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INTERIM PROTOCOL FOR DIVING OPERATIONS IN CONTAMINATED WATER

by

Richard P. Traver, P.E.
Senior Research Engineer/Unit Diving Officer
Releases Control Branch
U.S. Environmental Protection Agency
Edison, New Jersey 08837

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HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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16. ABSTRACT

The purpose of this research program and resulting manual have been to improve and update EPA's safety capability which involve underwater hazardous chemical cleanup responses. The manual includes the assessment, testing, evaluation, and demonstration of commercial underwater protective suits, clothing, support equipment, and breathing apparatus in waters contaminated with hazardous substances that may be injurious to a diver's health. The manual also identifies specific types of "in-water" hazards, their location and effects upon divers, their equipment and considerations for protection surface support personnel. The major participates and beneficiaries of this program sponsored by the EPA and NOAA are the U.S. Coast Guard, U.S. Army Corps of Engineers, Department of Energy, Association of Diving Contractors, and the many local underwater search and recovery units.

The helmets which were successfully evaluated for chemical exclusion were the Draeger Helmet System, the Desco "Pot" Diving Hat, Diving Systems International Superlite-17B Helmet, Morse Engineering MK-12 Navy Deep Water Helmet System, and Safety Sea Systems SS-20 Helmax Helmet. Seven different suit configurations were evaluated along with the above stated helmets. One diving dress was from Draeger with the remaining six supplied by Viking Diving Systems.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

Under normal EPA surveillance, analysis, and research activities, bottom mud and biota samples are regularly obtained from polluted waterways. Also under the authorities of Section 311 of the Clean Water Act and the Comprehensive Environmental Response Compensation and Liability Act (Superfund), governmental personnel from the USEPA, Coast Guard Strike Teams, National Oceanic and Atmospheric Administration (NOAA), and the Navy are required to perform work functions in hazardously contaminated underwater environments. In many cases these exposures have resulted in acute injury to the diving personnel. Long-term or chronic effects of diver exposure to contaminated waters is not well documented; however, in many cases these exposures have resulted in acute injury to diving personnel.

The EPA, recognizing the need to assess, modify, and evaluate commercially available diving helmets and dress, entered into an interagency agreement with the National Oceanic & Atmospheric Administration. The expedited preparation of this "Manual of Practice" is done as in "Interim Protocol." The contents of this document are based upon preliminary field evaluations of diving equipment in controlled chemical underwater environments.

Following the peer review of this document by the "User Community", the methods, procedures, equipment, and training, it is anticipated, will be applied at a number of sites or spills of opportunity. The resulting information gained from these field responses will allow for informed final editing of this "Manual of Practice." The anticipated completion of the final MOP is scheduled for December 1985.

David G. Stephan, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

The purpose of the subject Interagency Agreement (IAG) with NOAA has been to improve and update EPA's safety capability which involve underwater hazadous chemical cleanup responses. It has included the assessment, testing evaluation, and demonstration of commercial underwater protective suits, clothing, support equipment, and breathing apparatus in waters contaminated with hazardous substances that may be injurious to a diver's health. The field evaluation/demonstration of the equipment and protocol developed under this joint federal agency effort was held August 27-31, 1984 at the NOAA Sand Point Facility, Seattle, Washington. The major participates and beneficiaries of this program sponsored by the EPA and NOAA were the U.S. Coast Guard, U.S. Army Corps of Engineers, Department of Energy and Association of Diving Contractors.

The IAG between the EPA and the NOAA Diving Operations Office was entered into on August 1981. Work performed by NOAA included the assessment of the need for chemical diving protection and the "state-of-the-art" for diving operations in hazardous environments. NOAA acquired and modified currently available commercial diving dress and helmets, and has carried on an ongoing training program of EPA personnel to meet the stringent NOAA diving standards. NOAA, EPA and Coast Guard have performed functional evaluations of the modified equipment. The EPA prepared chemical diving operations protocol is to be reviewed by the Coast Guard Strike Teams, Naval and Army Diving Units and the Associatin of Diving Contractors for application at a real world "spill of opportunity". The Seattle simulated "spill" was utilized to shakedown the newly developed procedures and modified equipment prior to being put into actual field response operations.

Numerous chemical diving suits and helmets have been reviewed for chemical exclusion and material compatability. Five specific diving helmets and seven suits or "dresses" have been modified and functionally evaluated at the White Oak Naval Underseas Weapons Tower located in Maryland. Equipment evaluations at White Oak had been performed during April, June, and October of 1982, and February and March of 1983.

NOAA and EPA coordinated a three day workshop/seminar entitled, "Protection of Divers in Waterways Receiving Hazardous Chemical, Pathogenic and Radioactive Substances Discharges". This meeting took place on November 8-12, 1982 at the Underseas Medical Society, Bethesda, Maryland. Aproximately 40 participants representing scientists and diving experts from government, military, industry and acedemia attended. The Coast Guard was well represented. The workshop proceedings (UMS Publication #CR-60(CW)2-1-83) are available by contacting the Underseas Medical Society at (301) 530-9225.

Initial evaluations of the modified commercial diving dresses and helmet assemblies were completed during March 1983 at the EPA Oil & Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located at the Earle Naval Weapons Station, Leonardo, New Jersey. This operation utilized a 5000 gallon tank containing ammonia and fluorescein dye tracers in which the suits were safely evaluated.

Subsequent chemical tank testing was performed at the NOAA Diving Unit located in Miami, Florida in December 1983 and February 1984. These series of tests extended the OHMSETT work by subjecting divers to water temperatures of up to 112°F to simulate conditions typically encountered within cooling cores of nuclear generation facilities. Medical data telemetry was applied using rectal thermometers for body core temperature monitoring and EKG pickups for heart rate. The results of these "hot-water" tests showed excellent performance of the "Suit-Under-Suit" diving ensemble specifically developed by NOAA for not only thermal regulation (cooling or heating) but as a positive pressure suit to exclude contaminates from the encapsulated diver even in the event of a suit breach.

The helmets which were successfully evaluated for chemical exclusion were the Draeger Helmet System, the Desco "Pot" Diving Hat, Diving Systems International Superlite-17B Helmet, Morse Engineering MK-12 Navy Deep Water Helmet System, and Safety Sea Systems SS-20 Helmax Helmet. Seven different suit configurations were evaluated along with the above stated helmets. One diving dress was from Draeger with the remaining six supplied by Viking Diving Systems.

Peer review comments from the "Interim Protocol" and additions from the detailed equipment and procedural evaluation plan will be refined into a draft "Field Operations Handbook and Manual for Chemical Diving". This document will hopefully be adopted for actual practice on a trial basis by the Coast Guard Strike Team. Comments will be incorporated into the final handbook scheduled for completion in December 1985.

This report covers a period from August 1981 to October 1984 and work was completed as of September 1984.

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The preparation of this document was accomplished by gathering vital information and related references from many different experts in the diving community and chemical spill response organizations located both in the public and private sectors. Without the expertise supplied by Dr. J. Morgan Wells, Jr., Director of the National Oceanic and Atmospheric Administration Diving Operations Office, the preparation of this manual of practice would not have been possible.

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SECTION 1

INTRODUCTION

This report is a Manual of Practice (MOP) and is intended to provide guidance to agencies which utilize divers in waterways of environmental quality that may be acutely or chronically detrimental to human health. This MOP is an interim document and is a precursor of the final MOP which is planned for release in December 1985.

The final MOP will be based on actual field evaluation and demonstration of modified equipment and newly-developed response procedures. The final MOP will be reviewed by approximately 25 experts from government agencies and private industry.

The present MOP document, however, though primarily based on preliminary field evaluation of diving dress and equipment in controlled chemically-contaminated underwater environments, offers practical information for immediate use as a guide to safer underwater operations. In addition, the present MOP document contains a compilation of information from two recently completed EPA studies entitled, "Evaluation of the Use of Divers and/or Remotely Operated Vehicles (ROV) in Chemically Contaminated Waters" and "Chemical Tank Testing of Modified Commercial Diving Helmets and Dress," as well as information from documents issued by other agencies. The present MOP will contain information on toxicity of the most prevalently spilled hazardous substances to enable the user to make a judgment on whether deploying divers into waters containing these contaminants is advisable or not. In summary, the present MOP will provide information on (1) evaluation of hazards, depending on the nature of contaminants present ("Go/No-Go" situations to determine whether diving is possible or not), (2) "when and "how" to utilize divers in hazardous environments, (3) medical and physiological implications of a diver's exposure, (4) state of the art review of diving and surface support personnel protection when they perform underwater tasks in contaminated waters, and (5) decontamination operations for diving personnel and equipment. The specific "Job" to which the MOP can be applied will depend on the user's particular needs. It should be stressed, however, that this MOP is intended to serve only as guidance.

Several agencies such as the Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), Navy, and Coast Guard are mandated by Federal law and regulations to engage in activities that require personnel to dive in hazardously contaminated underwater environments. Because of inadequate understanding of hazard and inadequate protection against it, many diving and surface support personnel have suffered acute injuries (2). Equipment deterioration has been responsible for at least one fatality and undoubtedly is responsible for many incidents of diver exposure to contaminants. Very little information is available on low-level exposure to contaminants which the divers or surface support personnel might have suffered. Only acute or immediate effects to exposures have been reported. Chronic, long-term toxicity has not been investigated. This is a serious problem which is just now being addressed by several government agencies.

Biological and chemical contamination are significant problems in most harbors, bays, and other natural bodies of water in the United States. Biological contamination results from sewage discharge, both treated and untreated. The dangers to divers in waters contaminated with pathogenic microorganisms are well recognized. NOAA has conducted research programs to modify and develop the best procedures and equipment that would protect divers against pathogenic microorganisms.

Spills of petroleum products, hazardous materials, and other miscellaneous materials are a very significant contributor to chemical contamination of waterways. Between the years of 1977-1981, 64,609 such spills were reported to the U.S. Coast Guard office of Marine Environment and Systems.(1) This represents a total of 7.5.6 x 10^6 gallons of material released into navigable waterways alone. From 1974 to 1981, 454 large spill or release incidents were reported, involving a total of 20.9 x 10^6 pounds of dry hazardous and other substances.

There is a steady increase, over the past decade, in the waterborne transport of petroleum and chemical products in the United States. It is expected that this trend will continue, thus increasing the potential for releases of these products into the waterways of the United States. Chemical contamination can take the form of corrosive substances or poisons which affect the human internal system on both an acute or chronic basis.

A review of current requirements of various governmental civilian and military agencies clearly demonstrates a need for underwater activity that involves diving in response to chemical release situations.

The tasks a diver may perform can be divided into seven different groups:

1. Damage Assessment: Divers can be used to assess the extent of damage sustained in an accident, primarily an accident involving vessels and pipelines. Damage assessment is usually done in response to a known leak or possible leak. The diver should have a basic understanding of the structure and construction of the object they are inspecting. If a vessel is involved, all of the standard safety considerations of diving under or around vessels must be observed by both divers and vessel personnel. (See Figure 1.1)

2. Location of Source: If a spill is noted in an area and an underwater source suspected, a diver can help to locate the source. For reasons of both safety and efficiency, consideration must be given to type of material, potential sources, current, bottom

contours, bottom type, search pattern, underwater position recording, etc.

3. Location of Material: For substances which sink in water, especially those that are not highly miscible or readily dissolvable, a diver can investigate the location of the spilled material and extent of contaminated area.

4. Containment/Cleanup: For materials on the bottom, underwater "fences" can be erected to contain spilled material for cleanup. Cleanup of the material can be done by divers using suction lifts, guiding small dredge-type scoops, etc. The effectiveness of cleanup operations, whether done underwater or from the surface, can also be investigated. Divers can also assist with the deployment of surface containment and cleanup equipment. (See Figures 1.2 and 1.3)

5. Recovery of Containers or Contents of Containers: Divers can be used to recover drums or other containers of chemicals that have been dumped or lost underwater. Hoses can also be affixed to containers (drums, barges, vessel compartments) and the contents of the containers can be pumped to the surface. (See Figure 1.4)

6. Repair/Maintenance: Divers can repair or maintain underwater equipment and structures in order to stop or prevent discharges.

7. Environmental Investigations: The scope of work a diver can perform here is limited only by the type of studies to be conducted or data to be gathered. Sediment and/or benthic sampling, flora/fauna observation or sampling, or various measurements can all be accomplished by divers.

Unfortunately, to date, there has been very limited capability for either government or private organizations to enter these environments safely to perform necessary tasks. Experience in these environments by all groups, government and private, have often resulted in injuries, primarily chemical burns, to the divers and/or surface support personnel handling contaminated umbilicals, lines, and diving gear. This means that because divers must continue working in chemically-contaminated waters, it is necessary to develop appropriate safety procedures and equipment to safeguard their health and welfare. In addition, because no procedure or equipment is foolproof during diving operations, divers should be warned against diving into waters containing any particularly toxic contaminant such as a pesticide, for example.

Another contamination problem can be caused by the inadvertent spilling of nuclear waste or the accidental discharge of radioactive coolant into the natural water system. Very special procedures are followed for deploying divers in nuclear reactor cooling cores (22). Spills of radioactive materials are usually identified with warning signs and cleaned up immediately after the spill occurs. This MOP will not address radioactive exposure to divers.

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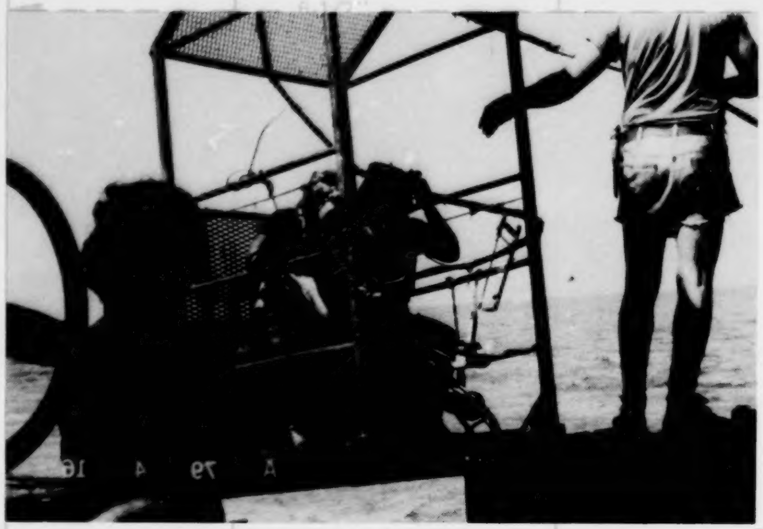
USCG Strike Team Recovery Operation of Air Florida Jetline Crash, 14th Street Bridge, Potomac River, Washington, D.C.



Deployment of Divers to Attempt Shutdown of Offshore Oil Plat-Form Blowout

Figue 1.1 Hazardous Chemical Underwater Tasks

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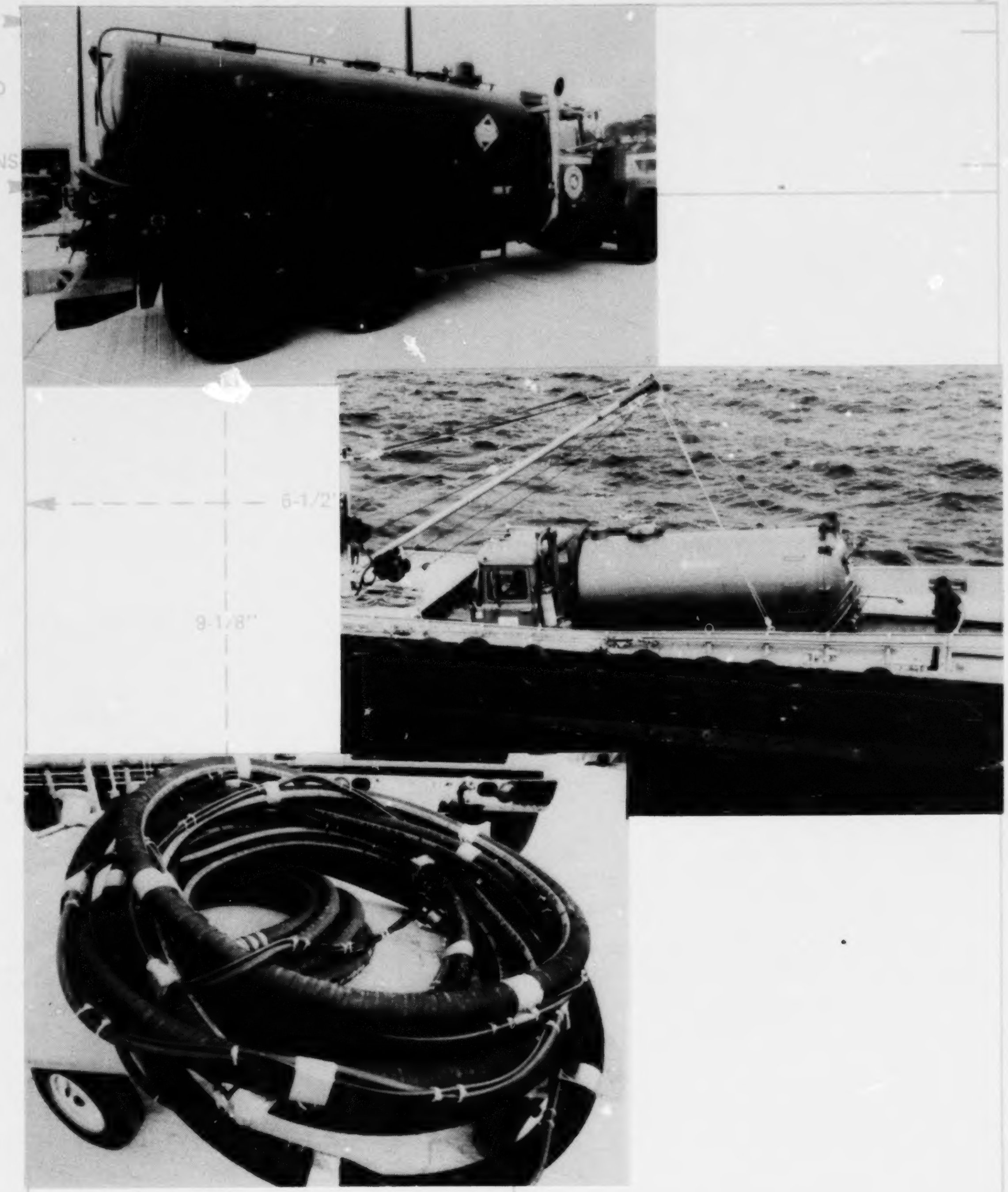

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Figure 1.2 Vacuum-Air Lift Trucks for Contaminated Underwater Sediment Removal

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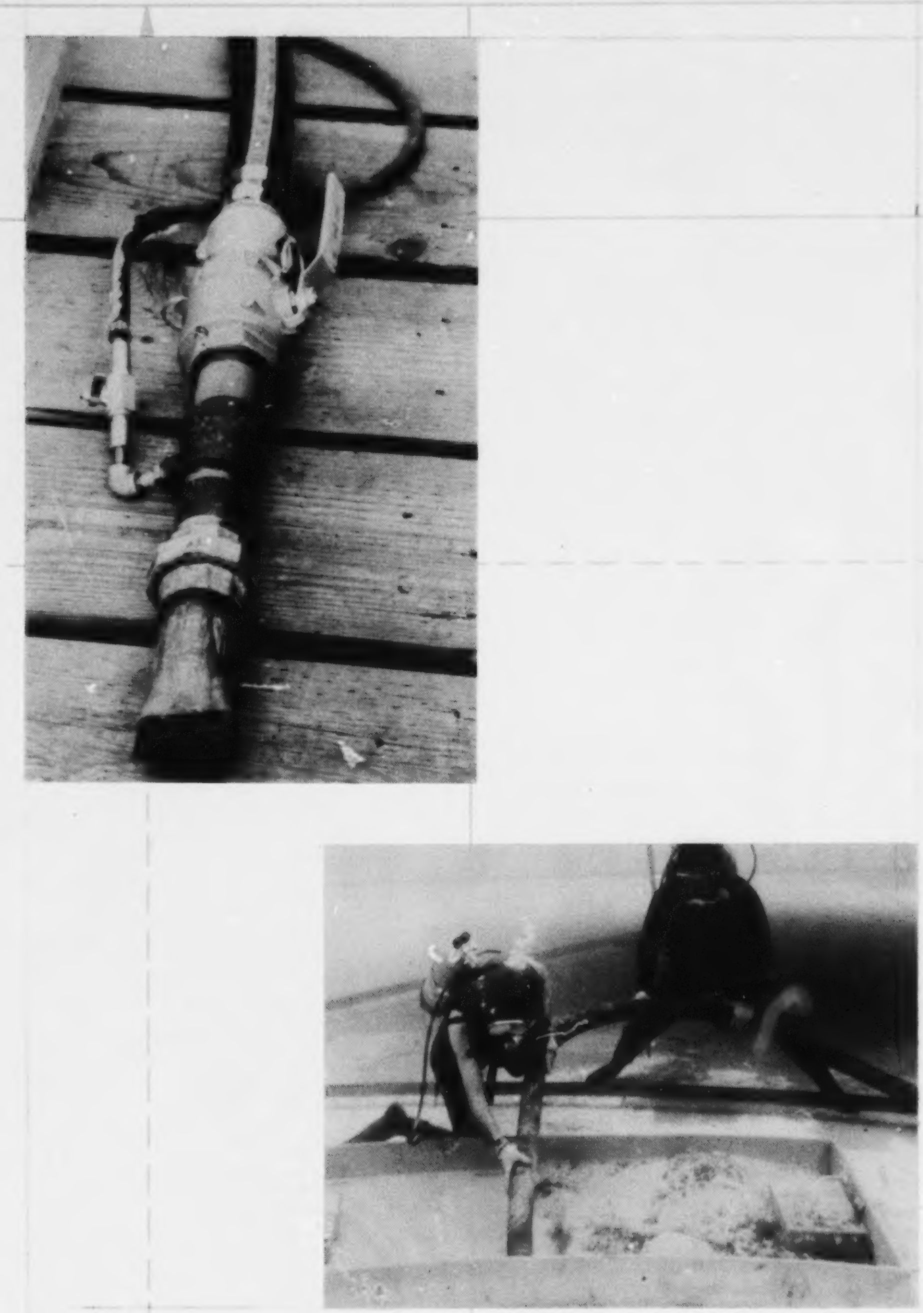

Figure 1.3 Diver Utilization of Vacuum Air-Lift for Removal of Contaminated Sediments

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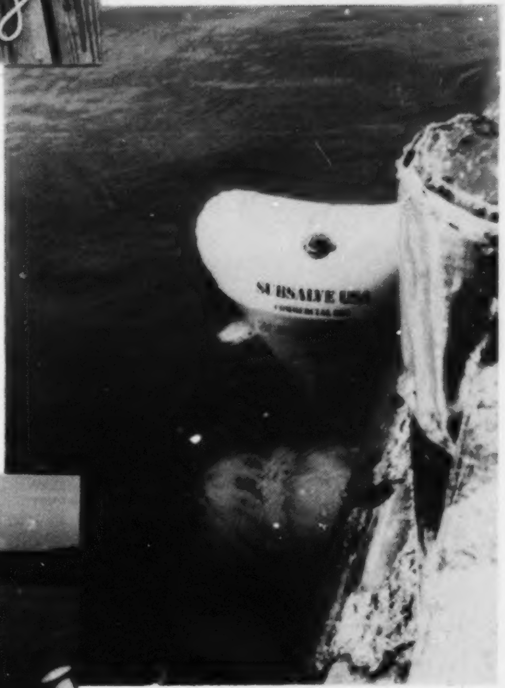
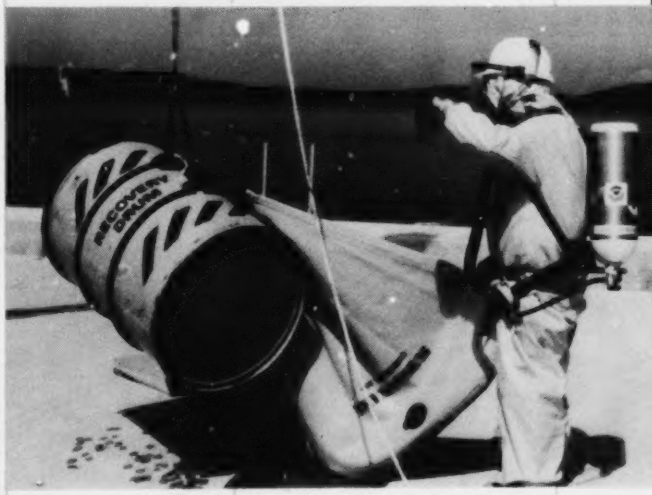
85 Gallon Overpack Recovery Drums



500# Air Lift Bag with Filled Overpack Recover Drum



Dockside Handling of Recovered Sunken Drum

Figure 1.4 Underwater Recovery of Sunken 55 Gallon Drums

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This MOP report will discuss very specific topics which are important to increased safety of diving operations. It is appropriate to review briefly the various types of diving operations.

Diving Tasks

Diving tasks can be conveniently broken down into five categories. These are commercial diving, military diving, support diving, and sport diving. Generally, commercial diving is surface-supplied diving and sport diving is Self-Contained Underwater Breathing Apparatus (SCUBA) diving. Military diving is predominantly surface-supplied diving, but there are some aspects of military duty that require the SCUBA diver. Research diving is predominantly SCUBA diving, but circumstances sometimes require the use of surface-supplied diving. Support diving is about equally divided between surface-supplied and SCUBA diving.

Commercial diving. There are three main commercial diving tasks: salvage diving, underwater construction, and the diving support for the offshore oil industry. There are some other forms of commercial diving, mostly harvesting of some type of shellfish usually for food or pearls.

Salvage diving often is nothing more than retrieving the contents of a sunken ship or plane. At times it involves a repair of a sunken ship's hull sufficiently to refloat the ship. Underwater construction is the second of these tasks. Bridges, tunnels, wharves, and harbors require commercial diving work during their construction. A new area of commercial diving has evolved in the support of the nuclear power industry for the changing of spent fuel rods within containment pools of reactor cores. The third area, the offshore oil industry, requires significant diving support which ranges from deep saturation dives to relatively shallow dives in support of the drilling platform.

Military diving. In many respects, military diving is very similar to commercial diving. The Navy has salvage tasks, and both the Navy and the Army do underwater construction. Submarine rescue diving is a unique application of salvage diving, where the salvage goal is to remove personnel from a sunken submarine. Another unique aspect of military diving is the combat role that some divers play. Navy SEAL and Underwater Demolition Teams use SCUBA diving as an integral part of their combat tactical operations. The Navy has been actively involved in research on saturation diving since the mid-sixties. The Man-in-the-Sea program was a full-scale demonstration of man's ability to live for extended periods underwater.

The U.S. Coast Guard National Strike Force is mandated by the Federal Water Pollution Control Act (FWPCA) "to provide assistance for oil and hazardous substance removal and shall have knowledge of ship's damage control techniques, diving and pollution removal techniques and methodologies".

During 1982 the diving billets for the National Strike Force were all moved to Elizabeth City, North Carolina, and on October 1, 1981, the

National Strike Force Dive Team officially became an element of the National Strike Force. The Dive Team is made up of two officers and thirteen enlisted divers. The divers are all trained at Navy Diving Schools and upon reporting to the Dive Team are fully committed to the diving program. The Team is equipped with SCUBA, lightweight surface-supplied systems utilizing Superlite 17's and MK 1 and Navy MK 12 deep sea systems. In addition, the Coast Guard has a wide variety of underwater damage assessment and control equipment. All of the Dive Team gear is designed and packaged for transport aboard C-130 aircraft or over the road. In the event of a hazardous materials spill or potential spill, the Dive Team would respond with as much equipment as could be effectively transported. As a minimum the Coast Guard would bring one of the surface-supplied systems, SCUBA gear, and damage assessment equipment. (See Figure 1.5)

Research diving. Research diving is a broad category that includes most of the nonmilitary diving done by the government and almost all diving done by universities and private foundations.

National government research organizations such as the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (USEPA), and the Smithsonian Institution routinely use divers in their work.

Scientists who work for the above research organizations collect data wherever they can be found. When it becomes necessary to search for information underwater, the scientist becomes a diver or uses the services of a diver. The same is true for scientists working with universities and private foundations. Most of this diving is SCUBA diving. It takes place in areas as remote as the Equatorial Pacific and the waters off the Antarctic mainland, but it also occurs in local harbors, lakes, and rivers.

With the exception of a few well-endowed private foundations, most of these diving activities have in common meager budgetary support. Equipment gets much use, and purchase of new equipment is rare.

Support diving. Support diving is a catchall category containing diving tasks that do not fit into any one of the other groupings. There are, however, several distinct tasks that actually fall under the general heading of support. Municipalities located near water usually have support divers attached to their police and sheriffs' offices to operate as search and recovery teams. Similarly, institutions having a waterborne capability usually employ a support diving team.

As the name implies, support divers are ancillary to the main effort. However, they usually accomplish something that cannot otherwise be achieved. For example, within NOAA, divers install tide and current gauges and clean ship bottoms as support divers, but they also collect scientific data and install underwater equipment as research divers.

Support divers for institutions and universities often perform similar kinds of diving. Their key function is support. Support divers working for municipalities perform various tasks in harbors and wharves. Those who

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USCG C-130 Transport

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USCG Strike Team
Emergency Response
Palletized Dive Gear

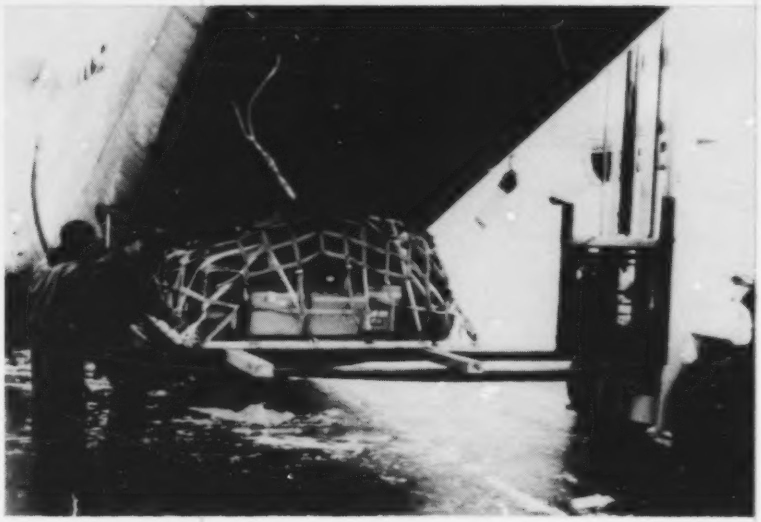

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Figure 1.5 Emergency Response of Specialized Dive Gear

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are diving for law enforcement agencies often search for evidence or retrieve bodies. Support divers rarely see clear, clean water and routinely are exposed to everything contained in the murky water they dive in.

Sport diving. There are two kinds of sport diving. The amateur sport diver dives for fun. The professional sport diver earns his livelihood from diving.

The amateur diver usually is one who has had some formal training and carries a certification card from one of the national certifying organizations. His diving activities tend to be limited to a few weekends during the warm season and to a diving vacation every so often. He is an underwater sightseer. Some amateurs, as they gain more experience, become underwater explorers, photographers, and hunters. The exploring is often in and around sunken ships, and these are frequently located in highly-polluted waters.

The professional diver usually is an instructor teaching other sport divers. Often he is also in the retail business, selling diving equipment or running charter dive trips. There are a few professional divers who make their living hunting for sunken treasures, and there are a number of professional divers who are also professional underwater photographers.

Diving Environment

The diving environment is a complex world that has been subject of countless papers and scientific writings over the years. Because we are primarily concerned with diving into contaminated waters, only three parameters--water temperature, water currents, and water contamination--will be briefly discussed. These are not the only parameters that affect the diver, but they have the most direct bearing when a diver is exposed to contaminants present in the water he dives into.

Water temperature is of major concern to the diver. The primary reason that the diver dresses in cumbersome diving suits is to protect himself against the cold. Cold water temperature can result in hypothermia and ultimately death if one is not protected against it. There are instances where the water temperature is too warm for comfort which is known as hyperthermia. Such an example is near Ensenada on the Baja Peninsula in Mexico. An underwater vent discharges geothermally-heated water at over 100 degrees Celsius, which is the boiling point of water. Generally, hot water is of human origin and can be found near power plant coolant discharge outlets, in nuclear reactor containment "ponds" and outer cooling canals, and similar locations. Encapsulated divers will also be subjected to hyperthermia because of their inability to "dump" internal body heat.

Water currents are usually something a diver considers when he plans his dive, something he must anticipate when swimming to the dive site, preparing for underwater salvage lifts, deployment of scientific data-gathering equipment, or when calculating his self-contained air supply. There are circumstances when the current becomes too strong to be compensated for by the diver's skill. NOAA divers installing current gauges will try to do the installation at slack water, but this is not always possible. Divers participating in hydrographic surveying are required to determine accurately the location and depth of underwater obstructions (such as wrecks). Quite often, these are located where currents pose hazards. These conditions often force the diver to use SCUBA when otherwise he would choose surface-supplied equipment. A surface-supplied umbilical increases the odds of becoming entangled, and an especially strong current can put enough force on the umbilical to pull a diver up from the bottom.

The third environmental condition tends to be more severe in the same high current areas discussed above. Biological and chemical contamination are significant problems in most harbors and bays. Biological contamination results from sewage discharge, both treated and untreated, and from agricultural feedlot runoff. Chemical contamination is the result of manufacturing pure products being accidentally spilled and chemical byproducts being intentionally released into rivers and coastal waters. Chemical contamination can take the form of corrosive substances or poisons that affect the human internal system on both an acute or chronic basis.

Another contamination problem can be caused by the inadvertent spilling of nuclear waste or the accidental discharge of radioactive coolant into the natural water system.

Of these three contamination problems, the chemical one generally is obvious, one can usually smell it or see discoloration; the nuclear one generally is clearly marked, and there probably are people actively involved in cleaning it up; but the biological one often is not at all obvious. The water can appear clean and taste fine, yet be seriously contaminated. Even the novice diver typically will stay away from water that is slicked and smells "funny." The authorities probably will not let him enter nuclear-contaminated water, but unless the diver has specialized knowledge or routine access to someone who does, even an experienced diver can find himself diving in seriously contaminated water and subsequently suffering the consequences.

It should be stressed that chemical contamination may also be unnoticed when a relatively low concentration of a tasteless and odorless substance is present.

SECTION 2

CONCLUSIONS

In today's society, hazardous materials are a common and essential commodity of commerce. Hazardous materials are used in great volumes in the production of all the items we consider to be common essentials of everyday life. These essentials run the spectrum from plastics to synthetic fabrics to pesticides. Indeed, in the common household most of the furnishings have required the use of several hazardous materials for their production.

Because they are used in large volumes, many of these hazardous materials are transported by tankers over road and rails and over water by barges and ships. And, as with all forms of transportation, accidents are not infrequent. In this case, however, an accident can have the compounding effect of endangering human health and the environment far removed from the scene as, for example, when a tractor-trailer wrecks and spills its cargo of highly toxic material into a river upstream of a township's drinking water reservoir. In such a case the leak must be plugged and the released material contained as quickly as possible to prevent it from entering the reservoir and endangering the health of the township's citizenry. Also, the safety and health of the response personnel is a major concern and that is the purpose of this manual.

It has been the purpose of this project to identify the problems, to locate immediate commercial solutions and to establish long and short-term goals for equipment and procedures development which will insure the health and safety of personnel who must work on, about, in, or under water when engaging in emergency or remedial response activities under Superfund, the Comprehensive Environmental Response Compensation and Liability Act.

It is expected that this project has begun to define the groundwork necessary to develop a hazardous substance diving operations standard for both underwater and surface support activities for use by on-scene coordinators responsible for the mitigation of hazardous substances releases under Superfund. The resultant hazardous substances diving standard should allow the on-scene coordinator to identify the special hazards which divers would be subjected to; to determine what dress and equipment for both divers and surface support personnel should be used in a specific instance; to specify the necessary decontamination procedures; and to insure the health monitoring of the divers.

The need for such a manual is immediate. Therefore, it is not the objective of this project to persue long-term research to develop new equipment or procedures, but rather to identify existing equipment and procedures which can be used as is or quickly modified or mated with other existing equipment and procedures to provide immediate protection to divers working in waters contaminated with hazardous materials. A secondary objective has been to identify the future research necessary to insure greater safety and capabilities in hazardous contaminated waterways.

The conclusions for the Manual of Practice are presented according to each section.

SECTION 4 - DEVELOPMENT OF THE MANUAL OF PRACTICE

4.1 A review of current requirements of various civilian and military agencies clearly demonstrates a need for underwater in response to chemical release situations. Capabilities for underwater activity in relation to damage assessment, location of products, containment/cleanup activities, environmental assessment, research studies, and other activities require that divers enter these contaminated environments. Unfortunately, there has been very limited capability for either government or private organizations to safely enter these environments to perform necessary tasks. Experience in these environments by all groups, government and private, have often resulted in injuries, primarily chemical burns, to the divers and/or surface support personnel. Very little information is available on low-level exposure to chemicals, the divers or surface support personnel may have received in these experiences. Only acute or immediate effects have been reported. Chronic, long-term toxicity has not been investigated. This is a potentially serious problem that is just now being addressed by several government agencies.

SECTION 5 - PATHOGENICALLY CONTAMINATED UNDERWATER OPERATIONS

5.1 Little or no information is available documenting diver infections. This creates a problem for attending physicians who are not knowledgeable about the kinds of microorganisms encountered in the aquatic environment, resulting in selection of antibiotics or other drugs for treatment being an element of chance.

SECTION 6 - ANALYSIS OF HAZARDOUS CHEMICAL MATERIALS RELEASE DATA

6.1 A review of actual spill data indicates that there are a significant number of incidents of toxic material release to the waterways, and that these releases pose a serious problem for both public health and safety and protection of the environment. The location of the majority of these releases indicate that most spills occur in protected river channels and port and harbor areas of the U.S. These areas not only allow the most significant potential for exposure of the general public to toxic substances, but also create some of the most complicated environments for spill response teams, primarily divers, to safely respond to these incidents. These facts indicate that efficient and safe response team equipment and procedures must be developed in order for various groups charged with spill investigation and cleanup activities, including underwater activity, to fulfill their mandated assignments to protect the health and welfare of the public and the environment.

6.2 The USCG strike team arbitrarily assumed that divers would be dispatched to spills of 10,000 gallons or more. This represents .6% of the 43,382 spills, 280 over three years, or 93 events a year. However, the 280 spills represent 80.3% of the total volume of spills or 32,900,000 gallons.

As indicated, most spills are in river channels, followed by port and harbors, then open coastal waters (primarily bays and estuaries).

6.3 Equipment problems in chemically contaminated water environments, primarily due to petroleum products, is well documented. Divers frequently enter these environments resulting in deterioration and failure of equipment. The problem is not only expensive but can be life threatening. Equipment deterioration is responsible for at least one fatality and undoubtedly responsible for many incidents of diver exposure to the contaminants.

6.4 There has been a very limited use of Remotely Operated Vehicles (ROV) technology in response to chemical release situations. Based on the analysis of underwater activity that would normally be useful in response to spill situations, ROVs may be able to contribute significantly by allowing certain underwater activities to be performed without having to risk placing a diver in the water. The current state-of-the-art with these vehicles limits their use primarily to inspection and evaluation of underwater conditions to determine whether or not a diver is necessary and to diver assistance tasks to increase the safety and effectiveness of the diver while in these environments. Underwater visibility and entanglement are viewed as the two most serious potential drawbacks to effective use of ROVs in these situations.

Because ROV technology is so new, there will probably be more varied and reliable uses of these vehicles in spill-response situations as development of the overall ROV industry progresses.

SECTION 13 - SELECTION OF SPECIFIC SELF-CONTAINED EQUIPMENT AND PROCEDURES FOR BIOLOGICAL HAZARDS

13.1 As a result of earler NOAA work (4) it has been demonstrated conclusively that divers do face biological hazard when they enter polluted waters. It has defined in general terms the scope of the bacteriological hazard. The probability that a virological hazard exists as well can be extrapolated from data available in the literature.

13.2 To quantify the microbiological hazard a diver can be facing a waterborne indicator organism, known to adhere to objects submerged in water, i.e. *Aeromonas* spp., was studied in great detail. *Aeromonas* spp. have been implicated in disease and it is now considered to be a pathogen capable of causing wound infections, gastroenteritis, and other disease states. Furthermore, it is associated with pollution. *Aeromonas* was found in significant numbers in almost every diving area examined in this study.

13.3 The ability to disinfect or decontaminate a diving suit, from bacteriological contamination so that the diver is protected when removing it, as well as support personnel assisting the diver and handling the gear, was confirmed.

13.4 In the absence of immediate, on-site, application of tests to evaluate the extent of hazards at a particular diving site, it is recommended that coastal areas (e.g. harbors and other sites near cities) routinely and minimally be considered to be bacteriologically contaminated from a diver protection standpoint, and appropriate measures be taken to protect the diver.

13.5 The most effective bacteriological protective gear and mode of operation is as follows:

Suits: The standard open celluar neoprene wet suit provides only thermal protection. Designed to be flooded during diving, the wet suit provides no barrier between the diver and the water. Because of its surface texture the wet suit picks up debris from the water, and can not be adequately cleaned and disinfected, resulting in the accumulation of infectious material and subsequent infection.

Three brands of variable volume dry suits were tested under the earler NOAA study: Unisuit; Aguala; and Viking. All provided excellent barriers for diver protection, assuming no leakage at critical points, e.g. around the face seal. Differences in effectiveness were apparent, however, especially in ease of disinfection. Through rinsing after use and spraying with a disinfectant inside and out, followed by rinsing, should avoid possible infection of the diver or support personnel.

Aquala and Viking suits responded very well. Each was equally easily disinfected. Treatment recommended is a fresh water rinse, 5-min disinfection contact time, thorough fresh water rinse, and air drying. Because of the high humidity atmosphere inside the suits, the interior should be exposed and subjected to disinfection as well. Betadine, Amway, and Zepamine disinfectants can be used with approximately equivalent results. They should be applied using a pressurized spraying apparatus for best effect.

Masks: AGA provided good protection, when properly sealed with the dry-suit hood. Better protection, but limited visibility, was afforded by KMB and Superlite 17 masks. Disinfection of these pieces of equipment is best accomplished by thorough rinsing, followed by wiping the interior with 70% alcohol and air-drying.

Air Supply: Demand mode appeared to be less of a problem than free flow, especially when communications equipment was used with the masks. When the free-flow mode was stopped and restarted, during periods of talking, the diver received an aerosol of water in his/her face, a potentially hazardous condition in polluted waters. Changes in the design of this equipment could alleviate the problem.

Clearly, the need exists for careful and thorough assessment of the potential bacteriological hazard to divers in any give diving area. In general, clarity of water is not a good indication of microbiological hazard (or lack of it), even though pollution may be obvious. Bacteriological analysis should be done, if not regularly, then at least initially. Among the most common infections occurring in divers unprotected by suitable gear is external otitis, an infection that can be aggravated, as we have reported in this study, by wearing protective diving hoods. Accordingly, it is recommended prophylactic use of acetic acid ear drops under all circumstances. Such medication is readily available.

13.6 If a biological hazard is suspected, a current biological analysis of the body of water may be available from the state health department. If current biological information is not available, samples can be taken and analyzed. Analysis time of a sample for biological hazards is generally on the order of days. If the suspected threat justifies the delay, an analysis should be made to substantiate and identify the biological hazard. If, however, a biological hazard is suspected and the criticality of the incident requires the use of divers but prevents biological analysis, the following safety measures should be used:

A. The divers should have current immunizations (i.e. appropriate prophylactic procedures should be used).
B. The divers should be completely encapsulated to prevent contamination.
C. The divers should be thoroughly decontaminated prior to desuiting.

SECTION 16 - HEAT STRESS IN ENCAPSULATED DIVERS

16.1 The diver is a very poor judge of his own thermal status.

16.2 The onset of serious consequences of hyperthermia can occur abruptly and often without obvious warning.

16.3 If hyperthermia is probable, appropriate monitoring of the diver's status should be conducted. Breathing rate determined by standard communication equipment can be a simple and reliable method. If an elevated breathing rate does not return to normal (for the particular diver) within two minutes after a diver is instructed to stop work, hyperthermia should be suspected and corrective action should be taken.

SECTION 18 - PERSONNEL PROTECTION FOR SURFACE SUPPORT OPERATIONS

18.1 Training is required of surface support personnel in the utilization of the type of protective gear used during diving and subsequent deconamination operations.

SECTION 19 - INCIDENT EVALUATION

19.1 OSC's will occasionally get "caught up" in the toxicology of the response, and will occasionally lose sight of the more common and mundane site consideration, i.e. oxygen content, explosive index, etc.

SECTION 20 - FIELD SAMPLING AND ANALYSIS

20.1 Sampling a chemical directly from its container is preferred. However, if direct sampling is not possible, samples may be taken close downstream of the container. Sampling methods may range from the use of conventional sampling equipment to the use of remotely controlled vehicles for sampling.

20.2 Once a sample has been taken, it must be analyzed. Conventional portable analysis equipment will provide rough quantitative data about the chemical which may or may not be adequate for identifying the chemical. The time required for analysis by portable equipment is generally only a few minutes. If more precise identification of the chemical is required, mobile laboratories are available through various government agencies and will provide precise analysis of the sample. Analysis by a mobile lab will require from a few minutes to a few hours. If time allows, conventional laboratories may be used for sample analysis. The total time required, including transportation and analysis of the sample, is generally several hours.

SECTION 21 - HAZARD EVALUATION: "GO" OR "NO-GO"

21.1 Evaluations should be made to determine whether too much emphasis is being placed on "worst case" approaches when responding to a hazardous substance spill or release.

21.2 The Marine Safety Officer (MSO), On-Scene Coordinator (OSC) or Response Officer (RO) must be allowed to make the decision that "no divers" or surface personnel enter "highly" contaminated "hot" areas.

SECTION 22 - GENERAL DIVING AND EMERGENCY PROCEDURES

22.1 Volatile substances must be considered when using diving bells and saturation systems.

22.2 Present commercially available radio communication systems do not always supply reliable or completely intelligible service. This situation complicates the surface support of diver tending and also adds additional risk to operations.

SECTION 3

RECOMMENDATIONS

Throughout the course of this project, as solutions and answers were sought to provide adequate protection to divers engaged in operations within biologically and/or chemically contaminated waterways, more and more questions and unknowns were revealed. As was stated in the conclusion section, the need for this manual is immediate. Due to time and budget limitations, project priorities were immediately indentified and pursued. Althogh some of the following recommendations were identified early in the project but not engaged, does not signify that they are minor ones and need not be pursued. The balance of the recommendations are the result of now knowing the limitations of our newly acquired knowledge, and recently tested modified diving dresses. It is hoped that some of the following items will be satified through actual operational adaptation, and that others will find support from appropriate sponsor agencies. As with the conclusions, the recommendations are presented by section.

SECTION 4 - DEVELOPMENT OF THE MANUAL OF PRACTICE

4.1 A survey of diving operations previously conducted in polluted water environments should be made. The cooperation of the Board of Directors of the Association of Diving Contractors (ADC) should be solicited at their next annual meeting with the emphasis of the purpose to be finding guidelines to help rather than rules to restrict. The little knowledge accumulated to date shows no acute effects of polluted water diving, but the potential of a problem exists and their assistance will help determine its magnitude.

4.2 Technology transfer of the information enclosed in this Interim Protocol must be made at the local regional level. This would allow for specific regional needs and situations to be assessed and adressed with regards to hazardous underwater operations.

It is therefore strongly recommended that one-day intensive technical overviews be presented at various EPA regional locations in the next year. The purpose of this seminar/workshop would be to thoroughly familiarize regional Marine Safety Officers and On-Scene-Coordinators to the contents of the Manual of Practice. This would include the identifications of underwater response tasks, problem and spill identification, hazard evaluation, modified diving equipment available for response, protection of surface support operations and decontamination procedures.

The sites of the seminars are proposed for the following locations:

- Washington, D.C. (EPA Regions I, II, III)
- Athens, GA (EPA Regions IV, VI)
- Chicago, IL (EPA Regions V, VII)
- Seattle, WA (EPA Regions VIII, IX, X)

The seminars would be strongly recommended for OSC's, MSO's, TAT, FIT, and USCG Strike Team personnel. It is also hoped that these seminars would be made open to the general commercial diving industry along with other interested governmental agencies. The following is a partial list of the various organizations who have requested copies of the final Manual of Practice:

National Oceanic and Atmospheric Administration
U.S. Naval Surface Weapons Center, Dahlgren, VA
U.S. Navy Experimental Diving Unit, Panama City, FL
U.S. Naval Medical Research Center, Bethesda, MD
U.S. Naval Supervisor of Salvage, Washington, DC
U.S. Naval Supervisor of Diving, Washington, DC
U.S. Coast Guard, National Strike Team, Elizabeth City, NC
U.S. Coast Guard Headquarters, Washington, DC
U.S. Army Corps of Engineers
U.S. Department of Energy
Underseas Medical Society
Cousteau Society
Association of Diving Contractors
Viking Diving Systems
Safety Sea Systems
Diving Systems International
Divers Institute of Technology
Suboceanic Consultants, Inc.
Nuclear Startup Services
Ocean Corporation
University of Maryland
International Underwater Contractors
Hamilton Research Ltd.
Virginia Highway Research Council
University of New Orleans
Diver Local Union 1026
Webb Associates

SECTION 7 - HAZARDOUS SUBSTANCES

7.1 Federal transportation regulations should be checked as to what "types" and "classes" of chemical substances are carried by bulk water transportation, i.e. barges, tankers. This information should be checked against the JRB Associates report entitled: "Evaluation of the use of Divers and/or Remotely Operated Vehicles in Waterways Contaminated by Hazardous Substances Discharges," by Steven A. McLellan, for amounts, frequency, geographical locations and types of chemicals most frequently spilled or released.

7.2 Longitudinal studies should focus on toxic chemical-pathogen interactions. It is critical to know what synergistic effects may occur, enhancing infection and/or disease. Data gathering now on this aspect of the hazard of diving in toxic chemical spills in sewage-polluted areas will prevent serious problems down the road.

SECTION 9 - USE OF THE HAZARDOUS SUBSTANCE DATA SHEET

9.1 Training is needed for OSC's, MSO's and RO's in the utilization and understanding of results obtained from rapid field response monitoring equipment such as the HNU, OVA, Microtox, Photovac, and Hach Hazardous Materials Identification kit.

SECTION 10 - DIVING PHYSIOLOGY

10.1 Compression of toxic vapors in the atmosphere in divers breathing air must be considered. At elevated pressures most toxic gaseous material become more toxic.

SECTION 14 - MODIFIED SURFACE - SUPPORTED DIVING SYSTEMS

14.1 Specific protocol and procedures need to be established for post-operation inspection and replacement of internal parts in breathing apparatus (diaphragms) and protective clothing.

14.2 Further testing and evaluation of suit and helmet modifications are necessary with various hazardous environments considered. Communication between agencies and companies need to be strengthened on the effectiveness of these modifications. The manufacturers themselves are interested in making the equipment more resistant, the modifications for polluted water may have useful adaptation to their standard models.

14.3 An ongoing listing of manufacturers currently producing modifications of diving equipment for use in polluted waters should be made available. The list should be open-ended to allow addition as new items or companies develop.

14.4 There is a need for chemical material compatibility information to be grouped according to suit models (both surface and underwater), and the chemicals they would come in contact with. Information should include the amount of exposure time and various chemical concentrations the suit material is subjected to before its integrity is rendered ineffective. Information as to cleanability of the specific suits and materials with respect to which specific decontamination solutions should also be included.

14.5 The Naval Surface Weapons Center is currently evaluating chemical permeation rates of various commercially available diving dress materials and helmet exhaust diaphrams. It is recommended that if a superior suit material is found, prototype diving dresses be thoroughly evaluated under the controlled chemical dive tank test environment which was developed under this program.

14.6 Investigations should be initiated in evaluating the Navy MK-14 self-contained rebreather system for possible full encapsulated diver operations. This system would eliminate the need for surface air supplied system, corresponding umbilicals, reduce the number of surface support personnel and allow for free swimming operations.

SECTION 15 - USING SURFACE SUPPLIED EQUIPMENT

15.1 The information, techniques and equipment developed under this program will be only as good as the individual's training. It is strongly recommended that NOAA, EPA and the USCG develop a "Hazardous Materials Diving Operations Course" which would be administered under the current NOAA training program. This course would be available to qualified military, government and selected civilian diving/response personnel. It is envisioned that such a course would be set-up in three separate week-long phases.

The first phase would be completion of the EPA Hazardous Material Incident Response Operations Course located in Edison, NJ. The second phase would be five days of "Hands-on" surface supplied diving operational training with the newly modified chemical diving dress at the Underseas Weapons Tower, White Oak, MD. The third phase of the training would be a week of actual field operational training.

The diving systems would include the U.S. Navy Mark-12 S.S.D.S., the Superlite 17B and the Helmax SS-20, all mated with modified heavy duty Viking dry suits or mated with a "Suit Under Suit" (S.U.S.) system developed by NOAA. The Superlite 17B has been modified to include a series exhaust valve (S.E.V.) and a second stage diaphragm protector. Viking dry suits would also be utilized with A.G.A. Divator full face masks for simulated response in pathogenically contaminated waterways.

To demonstrate each system, a number of taks would be performed over the 5 day period. The tasks envisioned at this time include, but are not limited to, the following:

1. Underwater location techniques using search patterns and pinger locators
2. Free liquid/solid recovery
3. Sediment sampling
4. Current meter installation
5. Drum overpacking and recovery
6. Tide gauge well installation
7. Underwater Cutting
8. Vacuum removal of chemically contaminated sediments

To further enhance the exercise, diving accident/management and hazardous environment scenarios would be incorporated. Operation would be staged from both dockside for harbor response and from a work tug for ship board shakedown.

Dives would be simulated under conditions that would require personnel protection and respiratory equipment for surface dive tenders decontamination of divers and support personnel.

A number of diver monitoring systems would be utilized during hazardous diving scenarios. The parameters that would be hard-wire telemetry monitored will include internal helmet gases and temperature, diver electrocardiogram, diver core temperature, and internal suit and helmet integrity.

SECTION 16 - HEAT STRESS IN ENCAPSULATED DIVERS

16.1 Information should be gathered in a readily available formate to allow the appropriate on-scene supervisor to decide when the most appropriate time/temperature level can be reached before utilizing body cooling devices. It must be recognized that a trade-off exists in the carrying of the extra weight and bulk of the cooling unit versus being warmer, but less encumbered.

16.2 Maintaining the diver cool during predive and postdive procedures can be advantageous.

SECTION 17 - MEDICAL MONITORING

17.1 Environmental/site monitoring for hazardous materials is considered more appropriate than routine medical monitoring. The latter should be conducted on a case by case basis. Otherwise, a comprehensive annual diving physical should constitute adequate routine medical surveillance.

17.2 Appropriate immunizations should be obtained by diving and support personnel who conduct operations in known polluted water. Routine: tetanus, typhoid and polio. High risk areas: Gamma globulin and others, as appropriate.

17.3 Available information on aquatic pathogen abundance and distribution and their drug susceptability should be consolidated and made available to medical personnel who treat divers and support personnel.

17.4 A study should be conducted to determine if the contamination of a diver might affect the way he can be medically treated, in the event he is injured. If contamination does affect treatment, then best estimates of proper treatment should be developed where possible. Also, if special equipment is required, it should be secured. If no known treatment is available for a given contamination, the Diving Supervisor may elect to not allow diving.

17.5 Specimens should be forwarded for processing to a designated laboratory to provide a data base documenting diver wounds, infections and illnesses directly associated with exposure to the aquatic environment so that a body of information can be gathered, from which guidelines for physicians and divers can be extracted to advance the everyday, practical medical care of divers.

17.6 A seroconversion study should be undertaken, whereby groups of divers are monitored prior to exposure, during and post-exposure to assess by serological methods actual exposure and immunological response. Surface support personnel provide a useful central group, as would commercial oystermen/divers to estimate chronic exposure to marine pathogens. An annual survey of divers should also be undertaken, in conjunction with the seroconversion study, via annual physical examination, to obtain a data base valuable for assessing diver risk, if any.

SECTION 18 - PERSONNEL PROTECTION FOR SURFACE SUPPORT OPERATIONS

18.1 The methods available to protect surface support crews at this time may preclude diving operations due to several factors. The current equipment is, as a rule, hot, heavy, and if SCBA is used, does not allow a sufficient length of time between changes of the SCBA system. These problems may be major drawbacks to being able to conduct diving operations in response to spills, even if adequate diver protection is available. Research is needed to refine available surface support protection equipment to eliminate or reduce these problems.

SECTION 19 - INCIDENT EVALUATION

19.1 A literature survey should be conducted on the compatibility of diving equipment with hazardous chemicals and the results made readily available through the one point contact.

19.2 A list of hazardous chemicals, grouped into categories of hazard levels, should be compiled and made readily available for the Diving Supervisor. Presently, the USCG National Response Center, the NOAA Haz-Mat Group and the JRB (3) have recommended lists of these types of chemicals. These lists should be compiled and the NRC designated as the point of contact. They have a toll-free phone number, operating 24 hours a day: 1-800-424-8802. The NOAA Haz-Mat Group should develop the capability to serve as the coordinating center for the diving-related aspects of the hazards of these chemicals.

19.3 Once on site, the Diving Supervisor should evaluate all factors which may affect the diving operations or plan of approach. These factors should include, but are not limited to, the following:

A. Environmental Conditions
   1. Weather
   2. Wind Conditions
   3. Current/Tide
   4. Water Turbidity
   5. Water Temperature

B. Containment Information
   1. Container Type and Volume
   2. Leakage Indication (Odor, Visible Sheen, etc.)
   3. Amount Remaining in Container
   4. Leakage

C. Location
  1. Depth
  2. Barriers/Obstacles
  3. Available Access
  4. Proximity to Medical Support

SECTION 20 - FIELD SAMPLING & ANALYSIS

20.1 Investigate the use of a stalk mounted underwater video system to remotely survey the location of sunken materials, drums or assess bottom conditions from a surface platform.

SECTION 21 - HAZARD EVALUATION: "GO" OR "NO-GO"

21.1 The Supervisor should consider the complexity of the diving operation first (how deep, how long, weather conditions, etc.) and the problems of the polluted atmosphere second.

21.2 A decision "matrix" should be available, covering the following areas:

a) Application of diving operations
b) Preparations for diving in polluted waters
c) Operational procedures for polluted waters
d) Decontamination procedures
e) Emergency procedures

SECTION 24 - DECONTAMINATION PROCEDURES

24.1 Proper procedures to safely remove the chemical contaminants from diving equipment and surface tending personnel must be developed. These procedures will depend on the type of contaminant and the degree of contact by surface support and diving personnel with the contaminant. These procedures must also address other areas of concern such as contamination of the divers support platform, maintenance of "clean" areas, and other factors.

24.2 Decontamination studies should be extended to develop procedures offering maximum effectiveness against pathogens and chemical agents and least damage to diving gear.

24.3 Penetration and offgassing of toxic material in breathing apparatus and hoses must be considered. Appropriate sampling protocols should be established.

24.4 There is a specific need to develop a protocol and procedure to test protective equipment, diving dress and helmets for contamination following decontamination operations. At what point or level of residual contamination should a piece of equipment be disposed?

24.5 Contaminated diving equipment should be properly disposed of if little is known about the desorption or decontamination of the contaminant from the equipment.

SECTION 4

DEVELOPMENT OF THE MANUAL OF PRACTICE

BACKGROUND

At the direction of EPA Releases Control Branch, JRB Associates prepared a document entitled, "Evaluation of the Use of Divers and/or Remotely Operated Vehicles (ROV) in Chemically Contaminated Waters."

This report documented the steady increase, over the past decade, in the waterborne transport of petroleum and chemical products in the U.S. It is expected that this trend will continue, thus increasing the potential for releases of these products into the waterways of the United States.

A review of actual spill data indicates that there are a significant number of incidents of toxic materials released to the waterways, and that these releases may pose a serious problem for both public health and safety, and for the protection of the environment. The location of the majority of these releases indicate that most spills occur in protected rivers, channels, ports, and harbor areas of the U.S. These areas not only have the most significant potential for exposing the general public to toxic substances, but also create some of the most complicated environments for spill response teams, primarily divers, to respond safely to these incidents. These facts indicate that efficient and safe response team equipment and procedures must be developed. This will permit the various groups responsible for spill investigation and cleanup activities, including underwater activity, to fulfill their mandated assignments to protect the health and welfare of the public and the environment.

A review of current requirements of various civilian, government, and military agencies clearly demonstrates a need for underwater activity which involves diving in response to chemical release situations. Capabilities for underwater activity in relation to damage assessment, location of products, containment/cleanup activities, environmental assessment, research studies, and other activities require that divers enter these contaminated environments. Unfortunately, there is a very limited capability for either government or private organizations to enter these environments safely to perform necessary tasks. Experience in these environments by all groups, government and private, has often resulted in injuries, primarily chemical burns, to the divers and/or surface support personnel. Very little information is available on low-level exposure to chemicals that the divers or surface support personnel may have received in these environments. Only acute or immediate effects have been reported. Chronic, long-term toxicity has not been investigated. This is a serious problem that is just now being addressed by several government agencies.

Equipment problems in chemically contaminated water environments, primarily due to petroleum products, are well documented. Divers frequently enter these environments and the result is deterioration and failure of equipment. This problem is not only expensive but can be life threatening. Equipment deterioration has been responsible for at least one fatality (3) and is responsible for many incidents of diver exposure to the contaminants.

There has been very limited use of remotely-operated vehicles (ROV) technology in response to chemical release situations. Based on the analysis of underwater activity that would normally be useful in response to spill situations, ROVs may be able to contribute significantly by allowing certain underwater activities to be performed without having to risk placing a diver in the water. The current state-of-the-art with these vehicles limits their use primarily to inspection and evaluation of underwater conditions in determining whether or not a diver is necessary, and if diving is possible to increase the safety and effectiveness of the diver while in these environments. Underwater visibility and entanglement are viewed as the two most serious potential drawbacks to effective use of ROVs in these situations.

Because ROV technology is so new, there will probably be more varied and reliable uses of these vehicles in spill-response situations as development of the ROV industry progresses. (See Figure 4.1)

An Interagency Agreement (#AD-13-F-2-826-0) between EPA and National Oceanic and Atmospheric Administration (NOAA) was enacted in August 1981 to improve and update safety capabilities which involve underwater hazardous chemical cleanup responses. The work scope includes the assessment, testing, evaluation, and demonstration of commercial underwater protective suits, clothing, support equipment, and breathing apparatus in waters contaminated with hazardous substances which may be injurious to a diver's health.

Under the EPA/NOAA IAG, a workshop/seminar entitled, "Protection of Divers in Waterways Receiving Hazardous Chemical, Pathogenic and Radioactive Substances Discharges," was held at the Undersea Medical Society on November 9-11, 1982. The proceedings from this workshop are now available (13). Participants at this meeting agreed unanimously that there is: (a) no way that divers can be prevented from working in hazardous environments, and (b) research and development are needed to modify commercially available diving dress and helmet assemblies to protect divers from hazardously-contaminated environments.

NOAA has extensive involvement and expertise in underwater diving. NOAA's activities include production of the NOAA Diving Manual, the development of certification standards, and the operation of a diver certification training program for civilian government divers. NOAA divers have participated in numerous research programs which involved diving in waters infested with pathogenic microorganisms. To protect its divers against

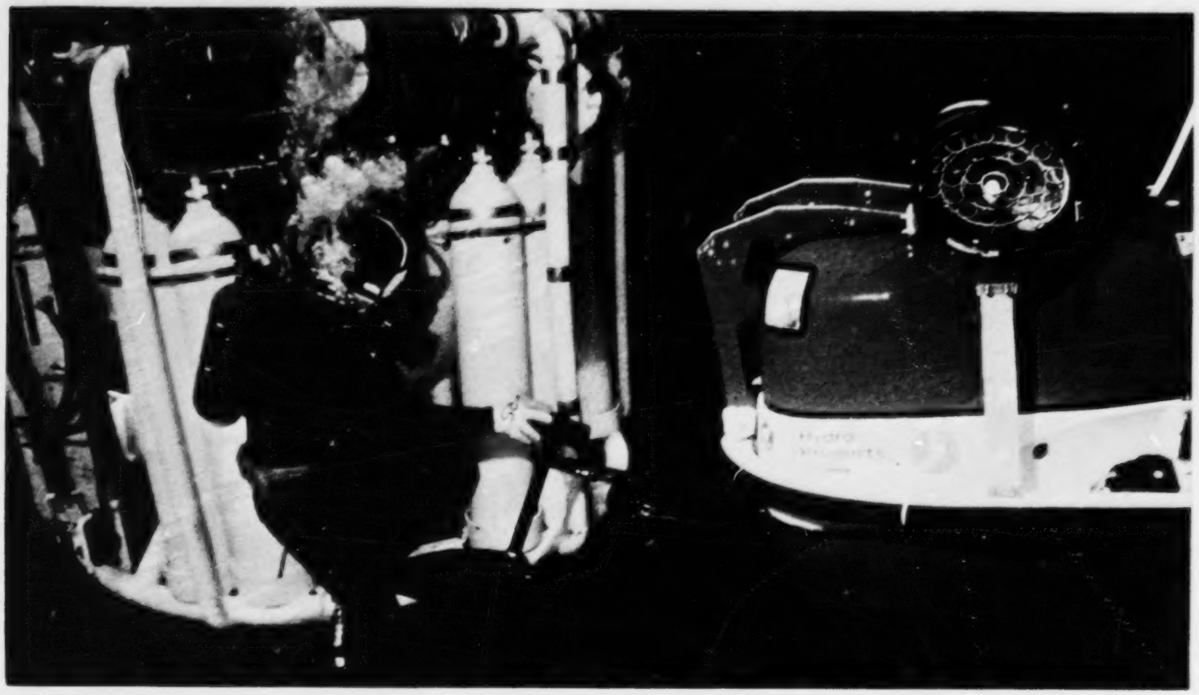

Figure 4.1 - Hydro Products RCV-150, Free Swimming, Tethered Remotely Controlled Vehicle Handing Diver Sledge Hammer

these microorganisms, procedures and equipment were modified or developed, and then tested. NOAA's experience in the development of protection for divers in water contaminated with microorganisms is, in many respects, applicable to protecting divers in waters contaminated with hazardous substances. NOAA continues to strive to improve its diver health and safety protection capabilities by conducting additional research and testing.

The successful accomplishment of various research and operational functions of both NOAA and EPA is dependent upon these organizations being able to have their own or commercial underwater divers operating safely in waters that are polluted with agents that are harmful to diver health and safety.

The performance of specific underwater functions during pollution cleanup or research efforts can save significant amounts of time and resources. Appropriate safety procedures and equipment are needed, however, in order to safeguard the health and welfare of underwater divers engaged in these activities.

Numerous commercial diving suits and helmets have been reviewed for chemical exclusion and material compatibility. Five specific diving dresses have been modified and evaluated functionally at the White Oak Naval Underseas Weapons Tower located in Maryland. Equipment evaluations at White Oak have been performed during April, June, and October of 1982, and in February and March of 1983.

No degree of static laboratory test will be adequate to determine the effectiveness of suit and helmet modifications. Actual dive operations are necessary to test equipment changes. This is caused by the various complexities of body movements and "in-water" positions during underwater work tasks. Seals and position straps can easily fail during strenuous diving operations, thereby allowing leakage of contaminants.

Many diving tanks exist in the various commercial companies and governmental agencies which serve as training sites for new diving personnel. However, none of these installations is capable of receiving either a representative pollutant or surrogate contaminate to allow for realistic, controlled testing and evaluation of newly modified diving gear. The existing EPA Oil & Hazardous Materials Simulation Environmental Test Tank (OHMSETT) is capable of simulating open-water diving conditions while providing suitable high-efficiency water treatment operations (see Appendix "A").

Initial evaluations of the modified commercial diving dresses and helmet assemblies were completed during March 1983 at OHMSETT which is located at the Earle Naval Weapons Station, Leonardo, New Jersey. This operation utilized a 5,000-gallon tank containing ammonia and fluorescein dye tracers in which the suits were safely evaluated.

The modified helmets, which were successfully evaluated for chemical exculsion, were the Draeger Helmet System, the Desco "Pot" Diving Hat, Diving Systems International Superlite-17B Helmet, Morse Engineering MK-12

Navy Deep Water Helmet System, and Safety Sea Systems Helmax Helmet. Six different suit configurations were evaluated along with the above stated helmets. One diving dress was from Draeger with the remaining five supplied by Viking Technical Rubber. The final Manual of Practice (MOP) protocol will describe the specific modification which were made to each diving helmet and dress.

The Manual of Practice (MOP) is intended to serve only as a guidance document for Governmental agencies and private organizations responding to incidents which require the intervention of underwater diving personnel. These dive teams carry out specific work tasks in waterways whose environmental quality may be acutely or chronically detrimental to personal health The procedures and protocols as presented will cover:

a. Hazard Evaluation;

b. "When and How" to Utilize Divers in Hazardous Environments;

c. Medical and Physiological Implications of Diver Exposure;

d. State-of-the-Art Review of Diver and Surface Support Hazardous Environment Protection;

e. Decontamination Operations for Diving Personnel and Equipment.

The publication and distribution of this "Interim Protocol" document at this time, prior to the completion of final field evaluation and demonstration of modified equipment and newly developed response procedures, is needed to serve as a reference guide to safer underwater operations. Field evaluation and shakedown of the procedures, techniques, and equipment descripted herein need to be conducted prior to the issuance of a complete finalized MOP. The final protocol will also include specific procedures and illustrations of the equipment modifications to the various diving dresses that have been evaluated.

The MOP will cover general procedural activities related to hazard evaluation, diver deployment and recovery, surface tending operations, and equipment decontamination procedures. Specific dive team organization will be detailed, describing each team members's job or task function. Both fixed diving platform (dockside) and shipboard operational organization and logistics will be presented in the final protocol.

Operations will generally fall in three scenarios: gross spillage of chemical(s) resulting from tanker collisions, sinkings, highway or rail accidents releasing contaminants directly into a waterway, or pipeline discharges; large general areas of contamination as the result of dumpsite (land) leachate and surface runoff generation, hazardous material release from open ocean dumping, long-term release from sunken drums and containers; and the trapping of hydrogen sulfide (H_2S) in underwater bottom depressions as the result of anaerobic biological activity, or high biological contamination in waterways receiving sanitary sewage discharges.

WORK TASK DESCRIPTION

Specific work tasks which diving personnel would be engaged in while exposed to hazardous water environments could include, but not limited to:

1. Classification/Determination of distribution and extent of contamination resulting from a release of heavier-than-water hazardous substances (solids and liquids);
2. Determination of the effectiveness of clean-up operations (e.g., dredging of spilled hazardous substances);
3. Conducting clean-up operations (e.g., operation of handheld dredges for vacuuming small pools of sunken hazardous substances);
4. Placement and retrieval of underwater sampling, monitoring or research equipment (e.g., sedimentation boxes, bottom benthos boring units, etc.);
5. Location and recovery of sunken containers of hazardous substances (e.g., drums, barrels, trailer truck container boxes, truck tankers, etc.);
6. Evaluation of the fate and effect of contaminents upon the aquatic environment.

AUDIENCE

The Manual of Practice (MOP) is intended for a selected audience of individuals who find it necessary to occasionally operate on and under hazardously contaminated waterways. The MOP is prepared for use by both the diving supervisor, diver, and surface tenders. Specific targeted user communities include: On-Scene-Coordinators (OSC); Marine Safety Officers (MSO); Military Diving Operations (i.e., Naval Supervisor of Diving; Naval Supervisor of Salvage; Naval Experimental Diving Unit; Naval Explosive Ordinance Disposal; Army Corp of Engineers; Coast Guard Strike Team; NOAA Hazardous Material Diving Unit); NASA Space Shuttle Recovery Unit; Department of Energy Nuclear Containment Diving Unit; Department of Transportation Bridge Inspection Unit; Association of Diving Contractors; regional, state, and county governments; scientific research agencies and academic organizations; and police, fire, and volunteer underwater recovery units.

Comments, corrections, additions, or deletions are actively encountered for incorporation in the final MOP. Your input is welcomed. Please address your information to:

Richard P. Traver
Releases Control Branch
U.S. Environmental Protection Agency
Raritan Depot - Woodbridge Avenue
Edison, NJ 08837
(201) 321-6677 - FTS 340-6677

Dr. J. Morgan Wells, Jr.
Diving Program Office
National Oceanic & Atmoppheric Admin.
6001 Executive Blvd.
Rockville, MD 20852
(202) 443-8007 - FTS 443-8007

Anthony P. Brown
Office of Health & Safety (PM-273)
U.S. Environmental Protection Agency
401 "M" Street, S.W.
Washington, DC 20460
(212) 382-3650 - FTS 382-3650

Lt. Richard Gaudiosi
Ship's Salvage Diving Officer
National Strike Team
U.S. Coast Guard
Elizabeth City, NC 27909
(919) 931-0268 - FTS 931-0268

SECTION 5

PATHOLOGICALLY CONTAMINATED UNDERWATER OPERATIONS

Waters are said to be polluted or contaminated if they look odd, smell funny, or if it is known that contaminants are being dumped into the water. Water need not look odd or smell funny to be contaminated, however. In the past decade the world-wide presence of a number of waterborne pathogens in polluted waters definitely has been established, and infections caused by some thirteen different organisms have been documented (Daily et al., 1980).

Daily and his colleagues (1980) found viable organism counts as high as 2 x 10^6 per millilitre (ml) in the Anacostia River in Washington, D.C., and counts to 760 per ml in the New York Bight. Coolbaugh and his colleagues (1982) found total organism counts in the Norfolk, Virginia, area of 14.0 x 10^5 per ml, counts ranging between 7.2 and 14.0 x 10^5 per ml in the Seattle, Washington, area, and counts ranging from 7.8 to 14.0 x 10^5 per ml in the New York area.

Divers and their equipment were found to be generally contaminated after diving in these waters. The contamination was particularly evident in the diver's ears and throats. Wound infection of a diver following a polluted water dive has also been reported. This report was able to trace a severe wound infection to two species of Aeromonas, one of which was resistant to some antibiotics. This antibiotic resistance was found in about nine percent of the Aeromonas isolated. The human diseases and symptomatic reactions that have been traced to waterborne pathogens or are known to be caused by them are many and varied. Table 5.1 contains a listing of most of these. The listing is not complete, but it does demonstrate the broad range of the contaminated water problem.

Sometimes divers (deliberately or inadvertently) work in waters marred by fecal pollution from sewage outfall or other sources. Herein, divers could be at risk of a wide variety of infections acquired by ingestion of even small quantities of polluted water. Among the most likely pathogens of concern would be: (1) hepatitis A and B viruses, (2) 27 nm viruses that cause gastroenteritis (Norwalk agent and related viruses), (3) bacterial pathogens that cause diarrheal disease including shigella, salmonella, and campylobacter. Shigella has been shown to be capable of initiating clinical infection in healthy young adults when as few as 10 organisms are ingested. Furthermore, epidemiological evidence in at least one instance has incriminated transmission of shigellosis occurring by divers swimming in contaminated river water. Campylobacter is also capable of initiating clinical infection when only a few hundred organisms are ingested.

TABLE 5.1. PATHOGENS KNOWN OR SUSPECTED TO INHABIT POLLUTED WATER AND SOME OF THEIR ASSOCIATED DISEASES

Pathogen	Disease
Acanthamoeba species	Amebic meningoencephalitis
Aeromonas species	Cholera like infections, septicemia, pneumonia
Capillaria philippnensis Capillaria hepatica	Nematode infection of intestinal or hepatic capillaries
Coxsacki viruses	Pleurodynia, aseptic meningitis
Dracunculus medinensis	Guinea worm disease, nematode infection of subcutaneous tissues with systemic symptoms and local ulceration
Echinococcus granulosis	Tapeworm infection with development of cysts usually in liver or lung
ECHO viruses	Associated with aseptic meningitis
Enteropathogenic Escherichia coli	Diarrhea in infants, occasionally in adults
Giardia lamblia	Chronic enterocolitis and mild to moderate diarrhea
Hepatitis virus	Infectious hepatitis
Legionella species	Pneumonia
Leptospira interrogans	Leptospirosis, hemorrhagic jaundice, Canicola fever
Mycobacterium tuberculosis	Tuberculosis
Naegleria fowleri	Amebic meningoencephalitis
Polio virus	Poliomyelitis
Pseudomonas aeruginosa	Urinary tract infections, cellulitis
Pseudomonas pseudomallei	Meliodosis, pulmonary infection, may have cavity formation, septicemia
Reovirus	Upper respiratory infections, gastrointestinal disease
Salmonella species	Typhoid fever, acute gastroenteritis
Schistosoma mansoni Schistosoma haematobium Schistosoma japonicum	Nematode infection of urinary or intestinal capillaries with damage of microcirculation
Vibrio species	Cholera, septicemia

Clinical Types of Infections That May Occur More Frequently In Divers

The diver wearing a wet suit and using SCUBA is in intimate contact with his aquatic environment. His skin, external auditory canals, nasal passages, and oral cavity all have some greater or lesser exposure to the water in which he is diving. Accordingly, the following are infections of the organ systems at risk that may become infected in the course of diving. In most instances there has been a description in the medical literature ascribing transmission of these infections through contact with an aquatic environment.

Sinusitis

The sinuses represent spaces or vaults within the cranial bones that are lined with respiratory epithelium and communicate with the nasal and oropharyngeal cavities by means of sinus ostia. Sinusitis is a well-recognized medical problem from which many divers suffer from time to time. In the course of purulent sinusitis, the affected sinus fails to communicate freely through its ostium and bacterial proliferation then occurs in the poorly draining sinus. Treatment involves measures to re-establish adequate communication through the sinus ostium and antibiotics to suppress the bacterial purulent infection. Antibiotic therapy is based on the best estimate of the species of bacteria involved and their sensitivity. It is conceivable that aquatic bacteria can colonize the sinuses and play a role in sinus infection.

Otitis Externa

Purulent infection of the external auditory canal, otitis externa, is an annoying infection most often acquired in the course of swimming or diving. The most frequent etiological agent, Pseudomonas aeruginosa, is an aquatic organism. Otitis externa is colloquially referred to as "swimmer's ear."

Conjunctivitis and Pharyngitis

There is no known evidence at present that incriminates the transmission of conjunctivitis or pharynigitis infections by means of aquatic contact.

Meningitis

Occasionally swimmers or divers in fresh water in the Middle Atlantic states develop a severe form of meningitis due to being infected with free-living amebae of the genera Naegleria or Acanthameba. These amebae reach the meninges by passages through the cribriform plate in the nasopharyngeal area.

Pneumonia

Theoretically, an increased incidence of pneumonia might occur in divers due to aerosol inoculation related to a regulator. This has not been recognized however.

Gastrointestinal Illnesses

Hepatitis A, shigellosis, salmonellosis, and campylobacteriosis have all been associated with ingestion of contaminated water. Shigellosis has been acquired by swimming in contaminated waters. *Aeromonas hydrophila* represents another enteric pathogen that lives in the aquatic environment and can cause enteric infection. Thus, these various enteric infections must be considered to be real hazards should divers unknowingly work in fecally contaminated waters without proper protection.

Skin

Any interruption of the integument can result in secondary infection due to an assortment of *Vibrio* or *Aeromonas* species and other bacteria in the aquatic environment. Other pathogens in the aquatic environment that can cause skin infection include *Erysipelothrix rhysiopathiae and Mycobacterium marinum.*

SECTION 6

ANALYSIS OF HAZARDOUS CHEMICAL MATERIALS RELEASE DATA

This section documents the types of material and release situations which could be encountered by divers and/or ROV's when responding to petroleum or chemical spills. The information presented below covers (1) waterborne transport of petroleum and chemical products, thus giving an indication as to the potential for products to enter the water; (2) the locations and relative volumes of spills based on actual spill data; (3) the types of material released and some properties of those materials; (4) a brief analysis of the source and cause of spills; and (5) a summary, based on the preceding information, of "typical" spill environments. The information in this section resulted from an analysis of data collected from the U.S. Coast Guard and U.S. Army Corps of Engineers. Over 2,000 individual spills were analyzed to determine the material, location, waterbody, quantity, source, and cause of the spills. (See Figure 6.1)

Vessel Transport of Materials

A review of data compiled by the U.S. Army Corps of Engineers for the years 1970 through 1979 indicates an almost steady increase in the volume of all types of freight carried on U.S. waterways. Vessel freight traffic has increased for all types of waterways as shown in Figure 6.1. Both foreign and domestic traffic have increased significantly.

An aspect of domestic waterborne commerce that has a significant influence on the location of spills is the relative proportions of cargo moved on various waterways. As can be seen in Figure 6.2, the vast majority of waterborne commerce is carried on the Mississippi River and Great Lakes systems. Less than 25 percent of all commerce is carried on other U.S. waterways.

Another interesting fact is that, since 1971, barges and other non-self-propelled vessels have consistently carried more than 60 percent of all domestic waterborne commerce. The importance of this fact will be evident later in this section in reference to the number of spills related to barge traffic. Barges carry approximately 94 percent of the commerce in the other areas and vice versa. As an example, while the Inland Waterways (geographical area) received 23.8 percent of the total number of spills, spills in inland waters accounted for 41 percent of the total volume spilled. The opposite is true of the Pacific area.

Almost every commodity known is at some time transported by water. However, only eight principal commodities account for the majority of all waterborne commerce. Table 6.1 shows the percentage breakdown of

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Chemical Foaming Agents in Elizabeth River, NJ

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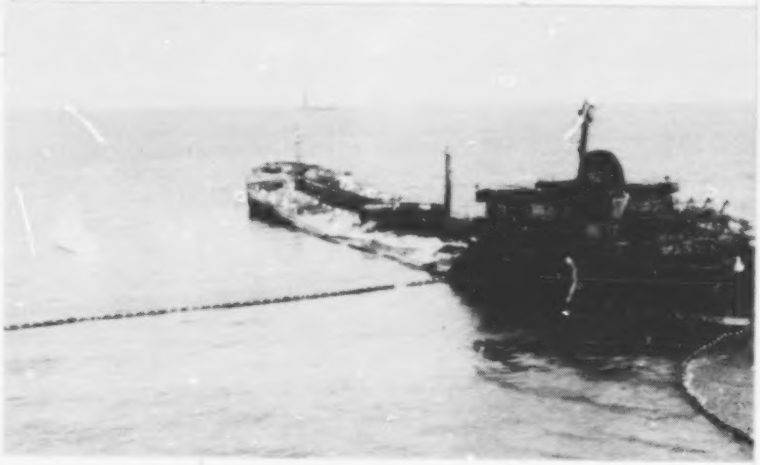
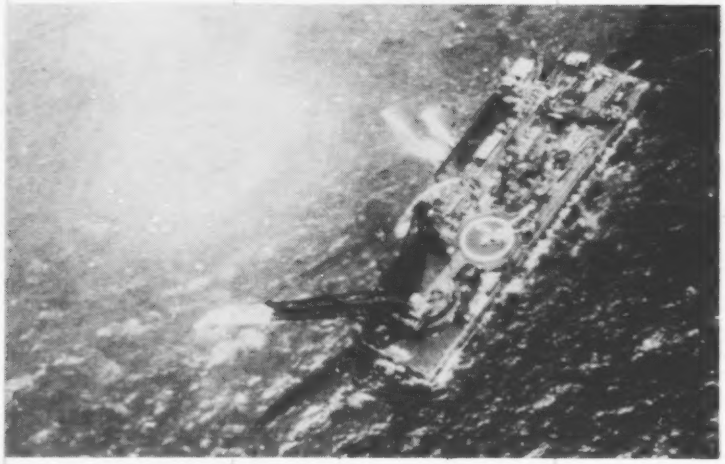


Shipboard Tanker Fires



Off Shore Oil Platform Blowout

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Figure 6.1 Examples of Hazardous Chemical Releases

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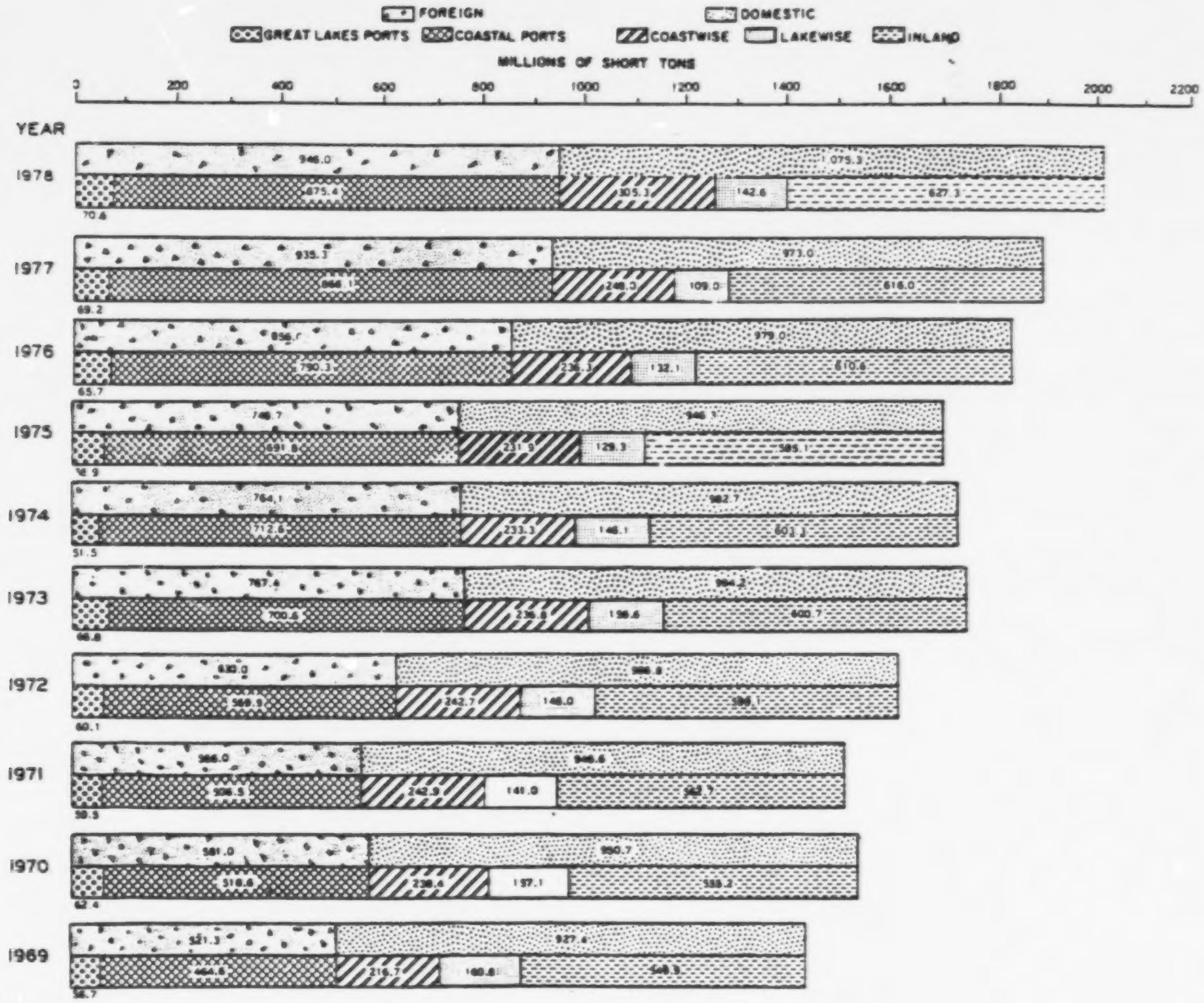


FIGURE 6.2. TOTAL WATERBORNE COMMERCE OF THE UNITED STATES, 1969-1978

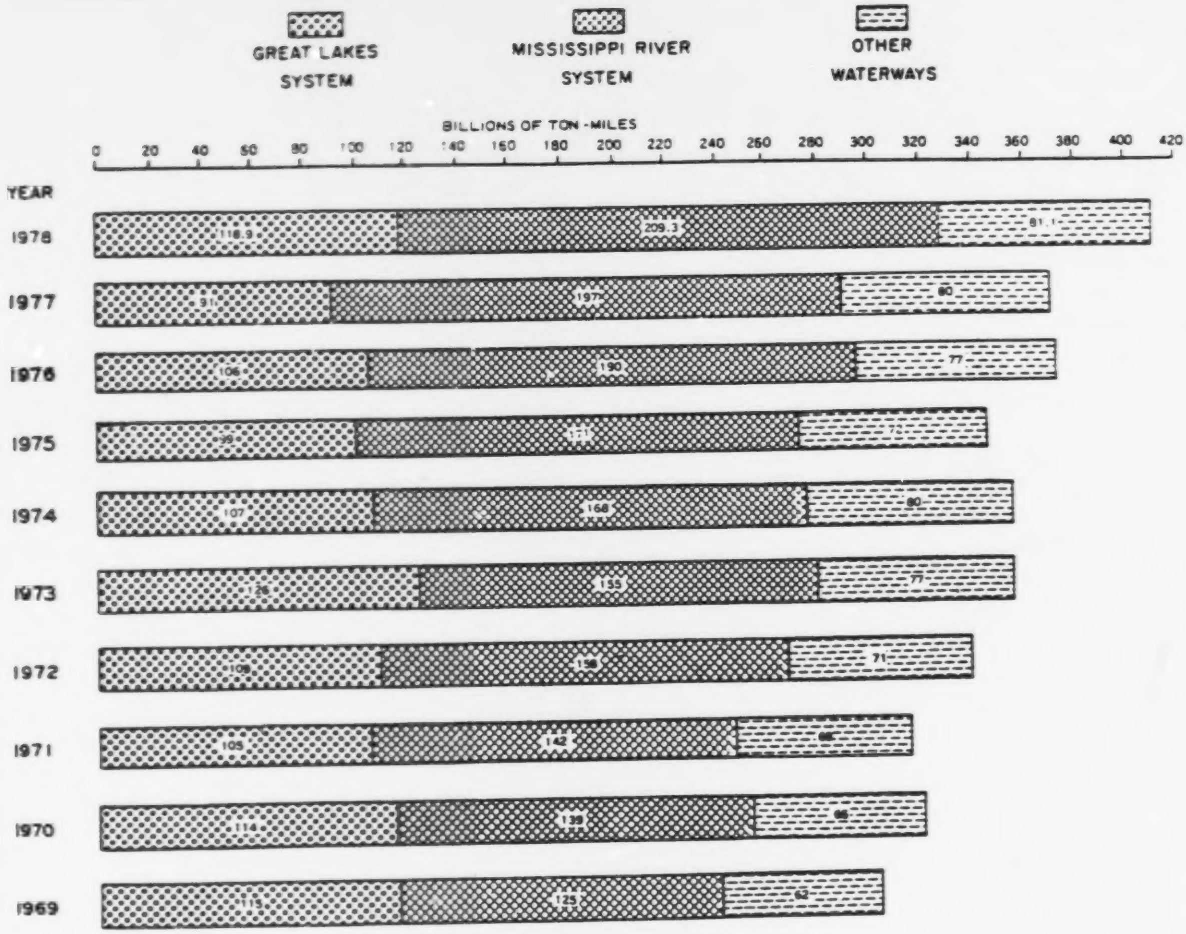


FIGURE 6.3. TON-MILES OF FREIGHT CARRIED ON THE WATERWAYS OF THE UNITED STATES, 1969-1978

	Foreign and Domestic		
	1977 Percent	1978 Percent	1979 Percent
Petroleum and products	49.1	48.7	46.5
Coal and coke	12.3	10.0	11.9
Iron ore, iron and stone	6.6	7.8	7.8
Sand, gravel and stone	5.4	5.8	5.5
Grains	6.2	6.9	7.3
Logs and lumber	2.8	2.6	2.7
Chemicals	5.3	5.1	5.5
Seashells	0.6	0.5	0.4
All other commodities	11.7	12.6	12.4
	100.0	100.0	100.0

TABLE 6.1. PRINCIPAL COMMODITIES IN WATERBORNE COMMERCE, YEARS 1977, 1978 and 1979

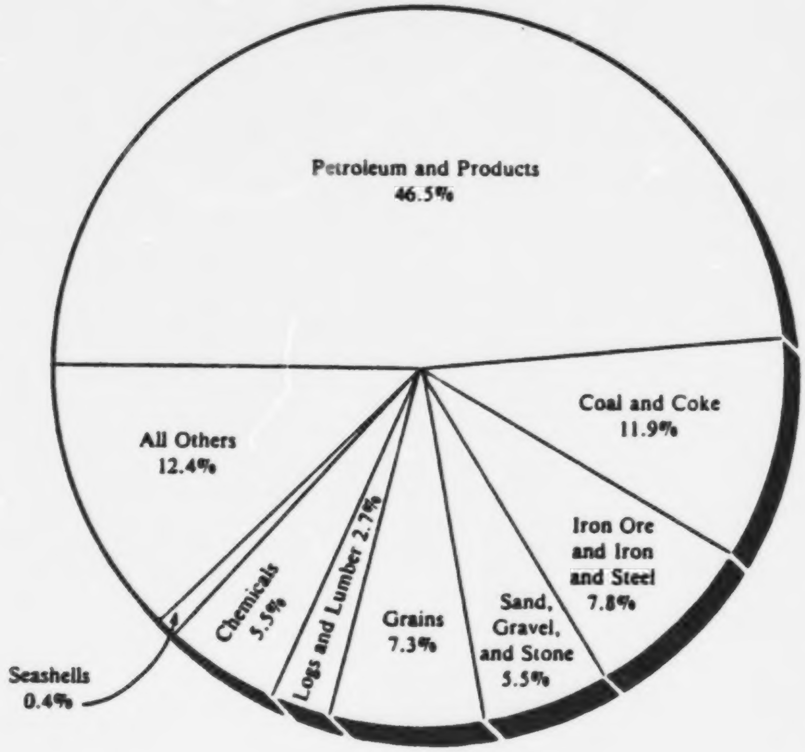


Figure 6.4 Principal Commodities Carried by Water

commodities transported in 1977, 1978, and 1979. As shown, the two commodities we are interested in, petroleum and chemicals, account for a significant percentage of all waterborne commerce. Figure 6.3 graphically depicts this information for 1979. The Corps of Engineers provides a further breakdown of the various groups of products or compounds that make up the two categories (see Table 6.2 and Table 6.3). Based on figures from these two tables, a potential of spillage of a certain material can be made based on the amount of that material transported. Many other variables will also have a great influence on the potential spill of these products, such as exact metod of transport, loading and unloading procedures, form of product (dry, liquid, etc.

As part of the evaluation, certain criteria were used to relate the spill information to situations where divers/ROV's would be useful. One of these criteria is volume. With regard to petroleum spills, it was felt that the volume of a spill would need to be sufficiently large in most cases to justify the use of divers/ROVs. The USCG Strike Force stated that it would be difficult to justify using divers for a spill volume under 10,000 gallons unless other extreme circumstances were present. Another criterion was that divers or ROVs would not be useful for spills onto beaches or into non-navigable waterways. Spills into these waterbodies were eliminated from further consideration.

Figure 6.5 indicates the location of all petroleum product spills greater than 10,000 gallons in the same manner as Figure 6.4. By considering the two criteria stated above, the results change significantly. The most revealing change is the comparison of the number and volume of spills over 10,000 gallons to the total number and volume of all spill. There were only 280 spills over 10,000 gallong which accounted for 0.6 percent of all spills (43,382). Yet this small fraction accounted for 80.3 percent of the total spill volume.

Most of these large spills occur in the inland, Atlantic, and Gulf areas and typically enter river channels or ports and harbors. The largest total volume of spilled products enter river channels and open coastal waters. However, there is a problem with this volume data, because, as detailed in Figure 6.6, two very large spills probably biased the relative proportions of products entering different locations. For this reason, Figure 6.7 may more accurately depict typical spill locations. As indicated, river channels, followed by ports, and harbors and open coastal waters (primarily bays and estuaries), receives the greatest number and volume of petroleum product spills. The geographical areas impacted most are the inland, Atlantic, and Pacific areas.

The "mega spills," like the two above, are infrequent enough that they should be viewed as individual incidents to be dealt with accordingly. Also not that these two spills along account for approximately 27 percent of the total volume spilled.

Hazardous Chemicals

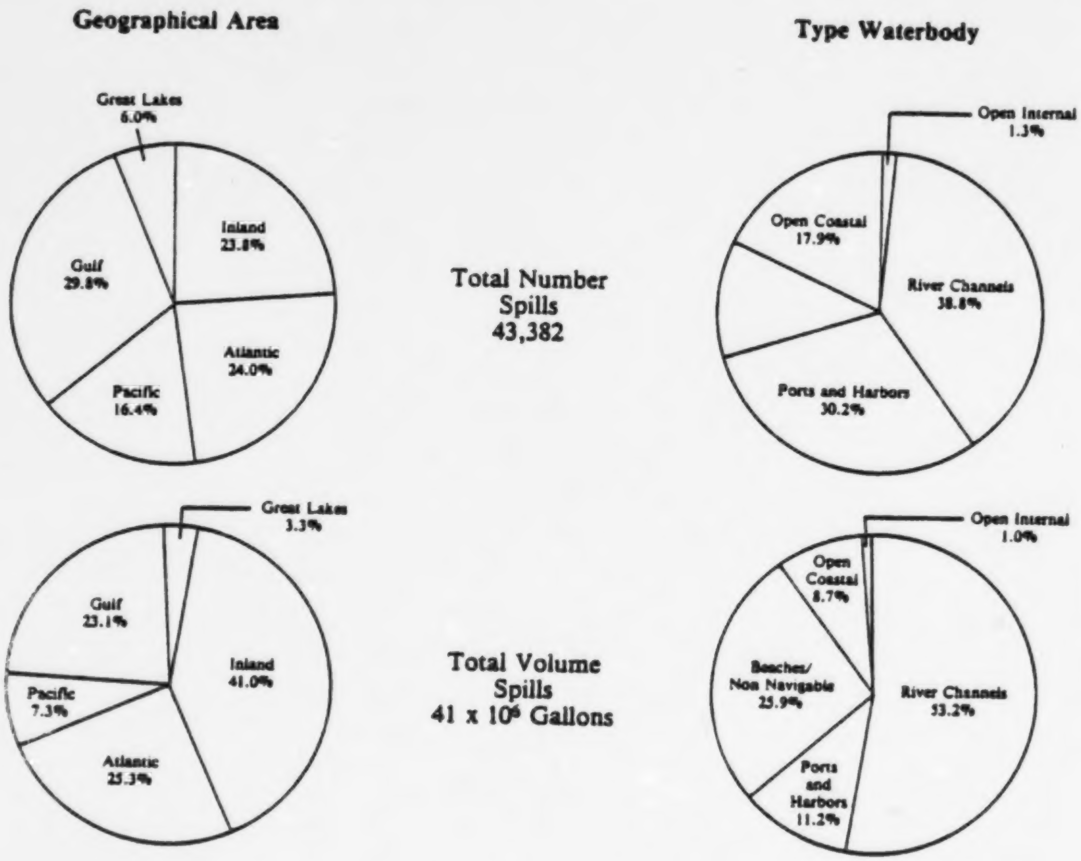
The location of hazardous chemical spills was analyzed in the same manner as petroleum spills. Figure 6.8 shows the primary location of all

	Percent
Crude Petroleum	53.8
Residual Fuel Oil	19.5
Gasoline	9.2
Distillate Fuel Oil	8.5
Coke, Including Petroleum Coke	1.9
Lubricating Oils and Greases	1.7
Jet Fuel	1.2
Asphalt, Tar, Pitches	1.0
Liquified Petroleum Gases	1.0
Naptha, Mineral Spirits, Solvents	0.8
Kerosene	0.4
Other Petroleum and Coal Products	0.3
Asphalt Building Materials	<0.1

Table 6.2 **Waterborne Commerce :** Petroleum Products

	Percent
Miscellaneous Chemical Products	47.3
Other Fertilizer Material	9.7
Nitrogenous Chemical Fertilizers	8.4
Sodium Hydroxide (Caustic Soda)	5.9
Benzene and Toluene	4.6
Phosphatic Chemical Fertilizers	4.6
Alcohols	4.4
Crude Coal Tar, Oil, Gas Products	4.0
Plastic Materials, Cellulose and Synthetic Resins	3.2
Sulphuric Acid	2.4
Potassic Chemical Fertilizers	2.3
Paints, Varnishes, Lacquers, Enamels	0.6
Soap, Detergent, Cleaning Preparations	0.5
Gum and Wood Chemicals	0.5
Synthetic Rubber	0.5
Synthetic Fibers	0.5
Insecticides, Fungicides, Pesticides, Disinfectants	0.2
Pharmaceuticals (Biological, Chemical, Medicinal)	0.1
Dyes, Organic Pigments, Dyeing and Tanning Materials	<0.1
Radioactive Materials, Including Wastes	<0.1

Table 6.3 **Waterborne Commerce:** Chemicals



^A^ 1980 data is preliminary

Figure 6.5 All Petroleum Product Spills (1977 through 1980)

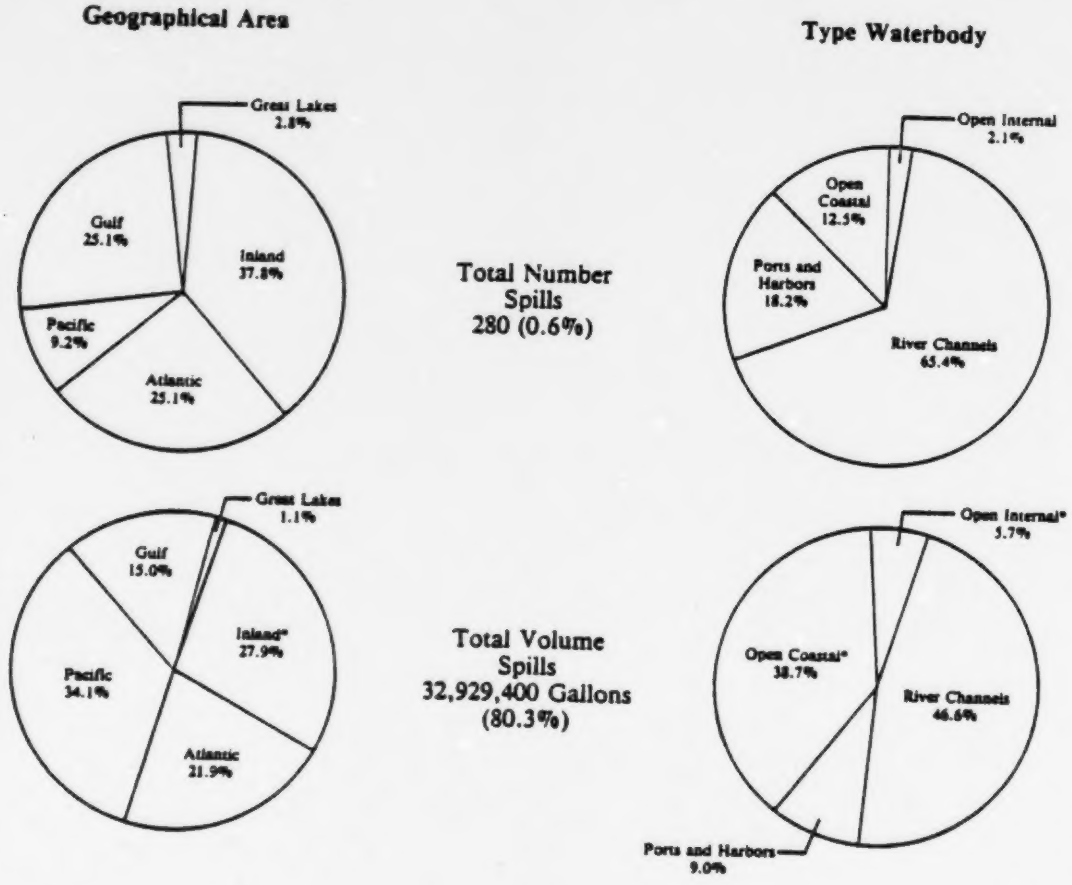
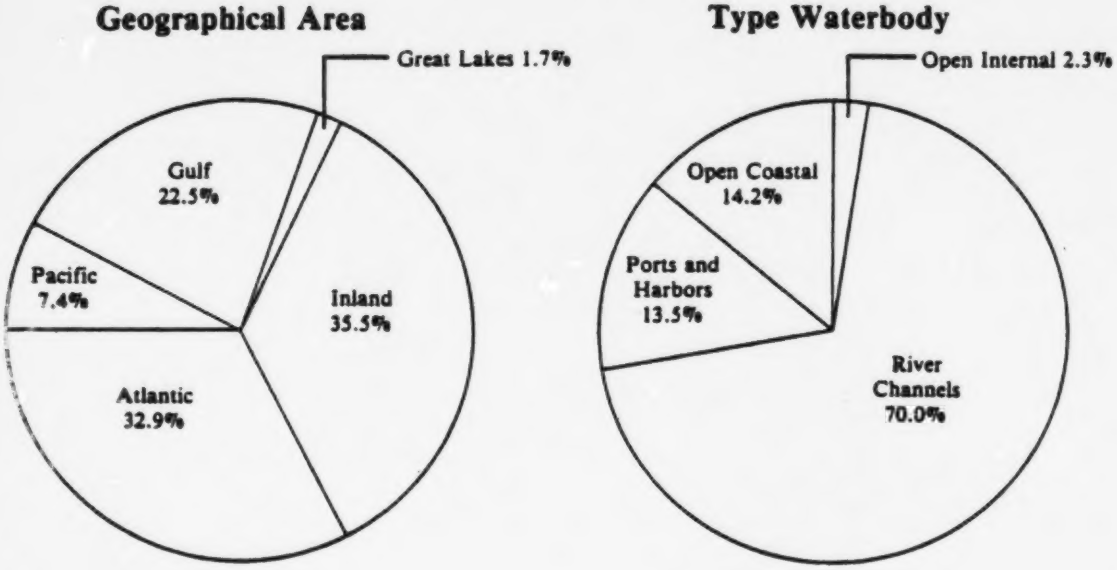
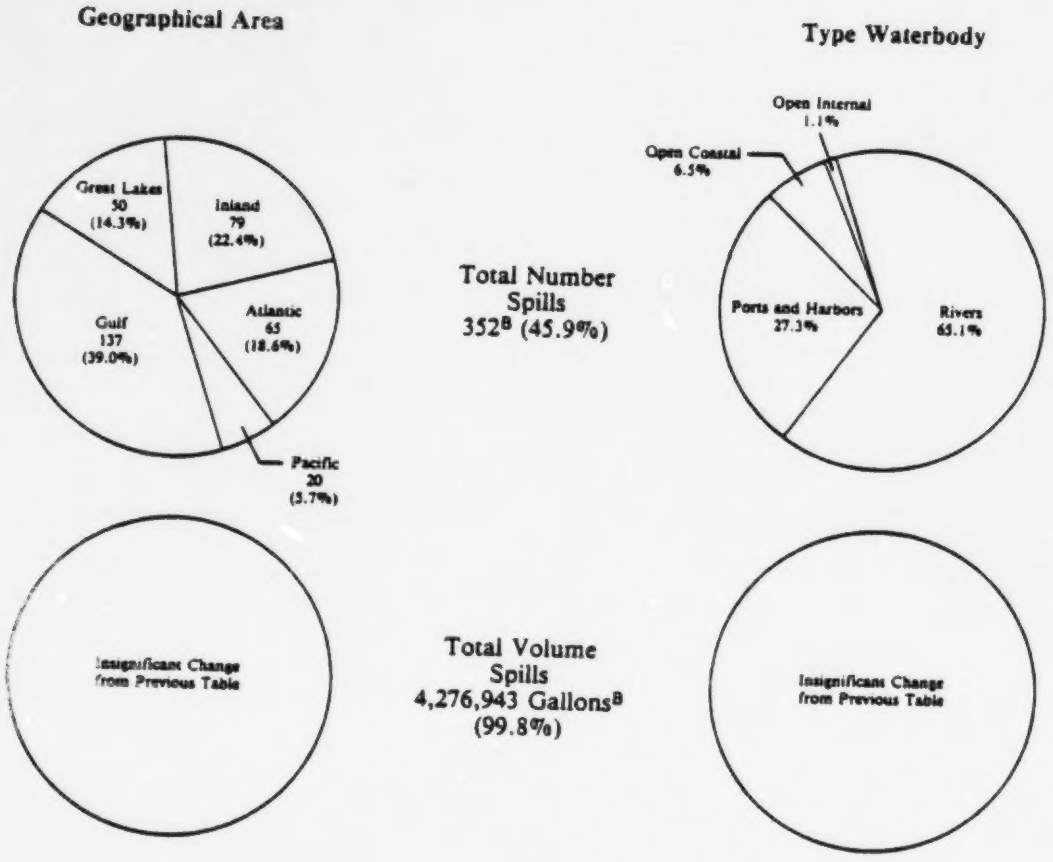


Figure 6.6 Location of Petroleum Product Spills >10,000 Gallons (1977 through 1980)



* 1977 tanker spill (9,600,000 gallons) in Hawaii (Pacific/Open Coastal) not included.
1978 onshore oil well explosion/fire (1,365,840 gallons) in Louisiana (Inland/Open Internal) not included.

Figure 6.7 Location of Petroleum Product Spills >10,000 Gallons (1977 through 1980) (Modified)



[A] 1980 data is preliminary

[B] 112 spills were of unknown quantity and are not included in the Spill Volume data

Figure 6.8 All Hazardous Chemical Spills >42 Gallons (1977 through 1980)

spills with the exception of those onto beaches or into non-navigable waters. Also note that there were 112 spills of unknown quantity. These spills were not included in the spill volume information analysis. Figure 6. indicates somewhat different locations for these products as opposed to petroleum. The Gulf receives the larger percentage of both number and volume of spills, followed by Inland and Atlantic. In respect to water-bodies, river channels again receive the largest number and volume of spills. The ports and harbors receive a large number of spills, but a comparatively small volume. The opposite is true of the open coastal category. These waters receive a relatively small number of spills but a large percentage of the total volume.

A volume criterion of at least 42 gallons of spilled material was established to help define situations in which divers/ROVs could be justified. This amount is a standard volume for a barrel. Using this criterion, Figure 6.8 shows the location of spills. Note that there are a total of 352 spills, not including the 112 of unknown volume, and these spills account for 45.9 percent of the total number of hazardous chemical spills. Yet these 352 spills account for 99.8 percent of the total volume of material spilled. Table 6.4 demonstrates this relationship between the size of a spill, the number of spills, and the total volume in a given range.

Types of Material Spilled and Material Properties

Information in this section concerning hazardous chemical spills will emphasize (1) the relative frequency and volume of spills; (2) the physical properties of the material spilled, which will help identify tasks required of a diver/ROV; (3) the material toxicity, and thus exposure risk to divers and surface support personnel; and (4) other hazards as may be defined. Information concerning the frequency and volume of spills is taken from PIRS data. All data concerning physical properties, toxicity, and other hazards is from published EPA, USCG, and National Institute of Occupational Safety and Health (NIOSH) literature.

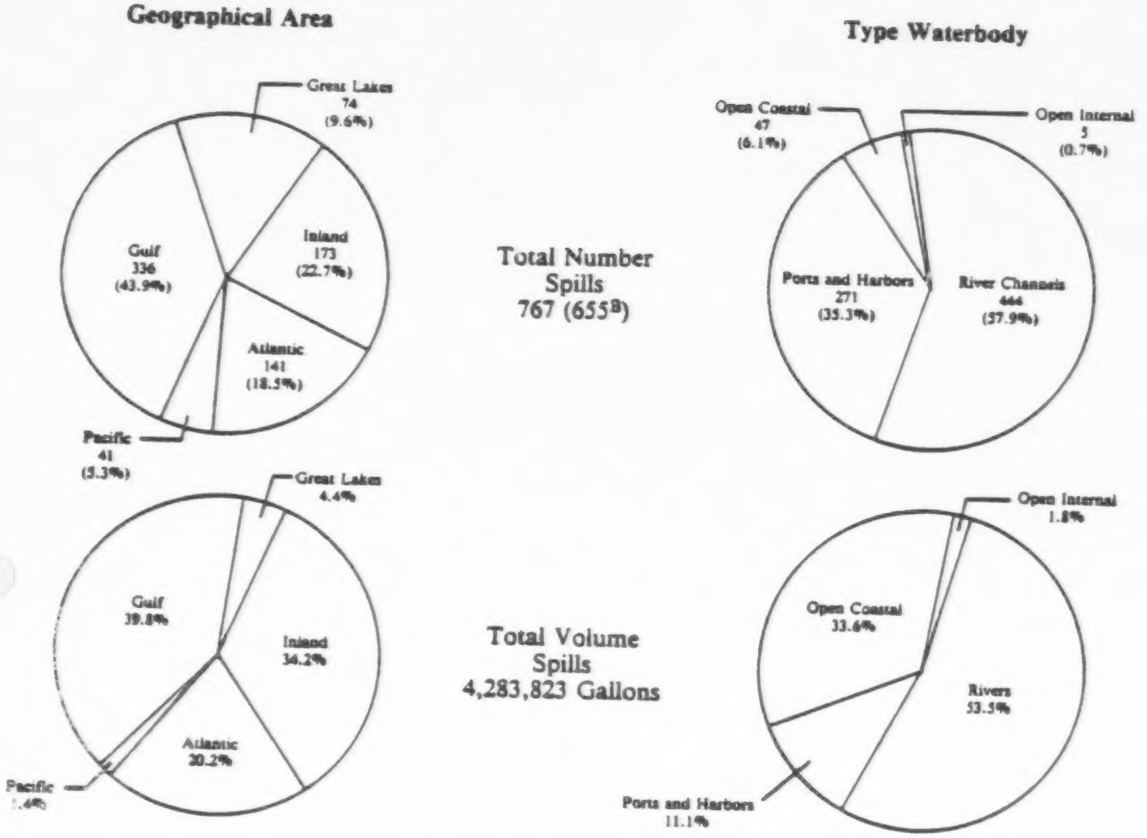
Analysis of petroleum product spills will be limited to the types of material spilled, frequency, and physical properties (floats/sinks) in water.

The criteria for this section are (1) petroleum product spills greater than 10,000 gallons per incident, (2) hazardous chemical spills greater than 42 gallons per incident, and (3) spills onto beaches/non-navigable water will not be considered.

Petroleum Products

Petroleum products have been grouped into eight different types of products. The type of product and the total number of spills during the period 1977 through 1980 are as follows:

Type of Product	Number of Spills
Crude Oil	79 (28.1%)
Diesel Oil	74 (26.4%)



[A] 1980 data is preliminary

[B] 112 spills were of unknown quantity and are not included in the Spill Volume data

Figure 6.9 All Hazardous Chemical Spills (1977 through 1980)
(Excluding Beaches/Non Navigable)

Spill Size (Gallons)	1977				1978				1979				1980^B			
	#	%	VOLUME	%	#	%	VOLUME	%	#	%	VOLUME	%	#	%	VOLUME	%
1- 9...	45	16.0	112	0.0	44	16.9	134	0.0	42	17.9	148	0.0	20	15.0	74	0.0
10- 49...	54	19.2	1,057	0.1	55	21.1	1,358	.1	55	23.5	1,286	.3	20	15.0	447	0.1
50- 99...	27	9.6	1,501	0.1	21	8.2	1,363	.1	16	6.8	951	.2	4	3.0	240	0.0
100- 499...	46	16.4	9,132	0.6	41	15.8	8,494	.4	30	12.8	6,200	1.4	20	15.0	3,411	0.5
500- 999...	15	5.3	9,520	0.7	8	3.2	4,472	.2	7	3.0	4,595	1.1	4	3.0	2,400	0.4
1,000- 2,499...	13	4.6	18,813	1.3	15	5.9	22,632	1.0	12	5.1	16,787	3.9	6	4.5	10,385	1.7
2,500- 4,999...	12	4.3	39,110	2.7	9	3.5	30,940	1.4	5	2.1	17,073	3.9	15	11.3	52,804	8.4
5,000- 9,999...	6	2.1	39,210	2.7	4	1.6	25,100	1.2	5	2.1	31,500	7.3	3	2.3	23,200	3.7
10,000- 49,999...	17	6.0	448,336	31.3	9	3.5	188,125	8.7	15	6.4	236,000	54.4	6	4.5	170,244	27.2
50,000- 99,999...	2	0.7	116,500	8.1	—	—	—	—	2	0.9	119,000	27.4	—	—	—	—
100,000-999,999...	1	0.3	750,000	52.3	3	1.1	621,228	28.7	—	—	—	—	1	0.8	362,260	57.9
>1,000,000...	—	—	—	0.0	1	.4	1,260,000	58.2	—	—	—	—	—	—	—	—
Unknown...	43	—	—	0.0	49	18.8	—	—	45	19.2	—	—	33	24.8	—	—
TOTAL...	281	100.0	1,433,291	100.0	259	100.0	2,163,846	100.0	234	100.0	433,540	100.0	132	100.0	625,465	100.0

[A] Includes Beaches/Non-navigable

[B] Preliminary Figures

Table 6.4 Hazardous Chemical Discharges

Type of Product	Number of Spills
Residual Fuel Oil	42 (15.0%)
Waste or Other Oil	32 (11.4%)
Gasoline	31 (11.4%)
Distillate Fuel Oil	14 (5.0%)
Asphalt, Creosote, Coat Tar	5 (1.7%)
Solvents	3 (1.0%)
TOTAL	280 (100%)

The majority of petroleum products will float on the surface of the water. It is for this reason that the emphasis in cleanup technologies has been geared primarily toward surface technologies. There are several petroleum compounds that do sink, or under certain conditions, primarily low temperatures, will sink. The general floating/sinking properties of the eight types of petroleum products listed are shown below:

Type of Product	Property
Crude Oil	Floats and sinks; various fractions separate and can behave independently.
Diesel Oil	Floats.
Residual Fuel Oil	Lighter fractions usually float. Heavy fractions, especially if cold and in fresh water, can sink.
Waste or Other Oil	Float or sink; depends on composition.
Gasoline	Floats; rapidly evaporates.
Distillate Fuel Oil	Floats; rapidly evaporates.
Asphalt, Creosote, Coal Tar	Sinks.
Solvents	Floats; rapidly evaporates.

The acute toxicity of petroleum products is usually related to the degree of refinement. All types are capable of causing chemical burns in prolonged contact with any area of exposed skin. Products which come in contact with the eyes, mucous membranes, and other sensitive areas of the body (lips, ears, armpit, genital area) have been shown to cause severe burns. Inhalation of fumes will often cause headache, nausea, and stuporous effects. Aspiration of the pure product can cause significant lung damage. Ingestion usually causes nausea and can burn the oral-upper gastrointestinal tract. Petroleum products are associated with several documented and suspected chronic effects such as skin irritation, skin cancer, mild aesthetic effects, chemical pneumonitis, central nervous system damage, and blood disorders.

As expected, there is also the potential for fire and/or explosion with most petroleum products.

Different sources of petroleum spills and the number of spills from each source during the period 1977 through 1980 are grouped into the seven categories listed below. Several of these categories have subgroupings of particular interest related to some type of underwater activity response.

Source	Number of Spills
Vessels (total)	118
- Tank ship	26
- Tank barge	69
- Other	23
Marine Facility	32
Vehicle Transportation	8
Transportation-Related Facility	5
Transportation Pipeline (total)	46
- Offshore Pipeline	1
Non-transportation-Related Facility (total)	50
- Offshore Production Platform	5
Miscellaneous	21

Of the 115 spills from vessels during this time period, 56 were from leaks in the hull or tank compartments that were caused by a collision or grounding incident. Barges are the most common source of these spills, and as was shown earlier, the majority of these spills occur in river channels or ports and harbors. Sixty-seven spills from various sources were caused by pipeline or hose ruptures or leaks. These three causes alone (vessel groundings/collisions and pipeline or hose ruptures) account for 44 percent of all of the large petroleum spills. Other major causes are equipment failure (other than pipe or hose rupture), personnel errors (tank overflow, misuse of equipment), and unknown causes.

The variety of hazardous chemicals far exceeds the variety of petroleum products. The properties, toxicity, and other hazards of these chemicals also vary greatly.

In order to address this problem in the perspective of how divers can be used, Table 6.5 lists the materials, number of spills (1976 through 1980), brief physical description, toxicity data, and general hazard data in the following groups based on their behavior in water:

a. Highly Soluble/Miscible Compounds
b. Slightly Soluble/Slowly Dissolving/Floating Compounds
c. Slightly Soluble/Slowly Dissolving/Sinking Compounds
d. Insoluble/Floating Compounds
e. Insoluble/Sinking Compounds
f. Compounds which Could React Violently with Water.

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS

FREQUENTLY SPILLED WATERBORNE CHEMICALS AND THEIR PHYSICAL PROPERTIES

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetone Cyanohydrin				1/2100		Floats and readily dissolves; readily decomposes to yield Hydrocyanic Acid (liquid and vapor--extremely toxic and explosive as a gas)	L -may slightly irritate eyes, skin, mucous membranes S -extremely toxic (as Hydrocyanic Acid) A -extremely toxic (as Hydrocyanic Acid)	Wear respirator, protective clothing
Ammonia	4/26005	7/101550		1/6000	7/2115	Colorless gas, dissolves readily in water, results in strong basic solution	L -very irritating to eyes and mucous membranes, somewhat irritating to skin S -slight A -high to moderate	Respirator and protective clothing advisable
Dimethylamine				1/4000		Colorless gas; liquifies at 45°F; soluble in water, resulting in strongly alkaline solution	L -skin burn S -low A -moderate	Very flammable
Ethyl Alcohol			1/30	1/42	1/6000	Clear, colorless liquid; completely miscible with water	L -none S -drunkeness A -low to moderate	Flammable, even when mixed with water
Ethylene Glycol	4/570			2/51	4/393654	Clear, colorless liquid; sinks and dissolves readily	L -none S -low A -low	Flammable
Hydrochloric Acid	10/16435	11/763115	6/4545	4/223	8/29150	Clear, colorless to slightly yellow liquid; miscible with water	L -Vapor--extreme irritation, liquid causes burns S -moderate A -moderate	Strongly Corrosive, Nonflammable

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Hydro-fluoric Acid		1/300	1/1500		1	Clear, colorless, mobile liquid; completely miscible with water	L -extreme irritation to eyes, skin, lungs S -high A -high to moderate	Cannot catch fire; wear respirator and protective clothing
Methyl Alcohol (Methanol)	3/251	2/1643	2/1260400			Clear, colorless, mobile liquid; miscible with water	L -may irritate; dries skin S -low, but high concentration may cause blindness A -low	Flammable
Nitric Acid		1/250			2/4001	Clear to light brown liquid	L -severe burns; vapor may cause total lung injury S -moderate to high A -moderate to high	Extremely caustic and reactive; wear respirator and protective clothing
Phenol	5/1328	6/13275	1/25000	1/50	3/123	Colorless to pink crystalline solid or fluid; sinks and dissolves readily	L -irritant, caustic to skin S -moderate to high (ingestion) A -high	Wear protective clothing
n-Propyl Alcohol				1/69000		Colorless liquid; completely miscible with water	L -practically none S -low A -moderate	Flammable
Sulfuric Acid	28/45385	19/11713	7/40480	12/57211	12/24515	Colorless to dark brown, dense, oily liquid; miscible with water, concentrated, reacts violently with water	L -extremely irritating vapor; liquid causes severe burns S -corrosive poison A -moderate	--

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Vinyl Acetate			4/135		1/2500	Colorless liquid; floats; liquid monomer is soluble solid polymer is insoluble	L -irritant; harmful vapor S -moderate A -moderate	Very flammable; respirator and protective clothing adviseable
Acetic Acid	5/31080	2/1000	3/3010			Colorless liquid; completely miscible	L -irritating, burning vapors and concentrated solutions S -nontoxic if dilute A -nontoxic if dilute, concentrated solutions very damaging	
Aluminum Sulfate					1/1000000	Shiny white solid; sinks and dissolves readily, forming an acid solution	L -low S -low A -low to moderate	--
Ammonium Compounds (Combination) Nitrate & Sulfate	2/3225	7/832	1/6000	6/50100	1/150000	White solids; sinks and dissolves in water	L -low S -low A -low to moderate	--
Chlorine			3/500	5/1515	1/4000	Greenish yellow gas, or clear amber compressed, liquified gas; sinks in water, slightly soluble	L -powerful irritant to skin and lungs S -corrosive to lungs and respiratory system A -very corrosive; highly toxic	Respirator and protective clothing advisable

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TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Chromium Compounds Chromic Salts (CrN) Chromous Salts (CrCl)	2/50	2/72	2/1300	3/15200		White to blue solid, sinks and is soluble in water	L -varying levels of irritation S -cumulative poison (liver damage), carcinogen A -high	--
Copper Compounds Nitrate Sulfate		2/600	2/573	3/85	1/200	Blue crystalline solid, sinks in water and dissolves readily	L -skin irritant S -low to moderate A -highly toxic	--
Lead Compounds Acetate Arsenate Chloride Nitrate Sulfate Tetra ethyl		3/7003		1/1980		Most are white crystals; sink in water, varying solubility	L -irritate S -cumulative poison; moderate A -high	For tetraethyl only: wear respirator and protective clothing
Maleic Anhydride					1/1970	Colorless needles; floats, hydrolyzes slowly to maleic acid, very soluble	L -very irritating S -low A -moderate	Protective clothing advisable
Nitrogen Dioxide			1/2000			Reddish brown gas; liquid below 72°F; sinks and dissolves, forming nitric acid and oxide	L -severe burns; lung injury S -moderate to high Nitric Acid A -moderate to high *NO_2 gas, deadly poison	Respirator and protective clothing

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Potassium Permanganate			2/510			Dark purple crystals; sinks and dissolves	L -irritant S -low A -high (fish and algae)	--
Sodium Bisulfite			2/2000			White, crystalline solid; sinks and dissolves to form acid solution	L -may irritate skin S -low A -moderate to high	--
Sodium Hydroxide	14/4350	9/6184	18/60454	14/47267	52/5700	White solid; sinks, very soluble	L -powerful caustic; burns tissue S -corrosive poison A -moderate to high	Very corrosive; protective clothing advisable
Sodium Hypochlorite			2/2500		1/50	Highly unstable crystals, dissolve in water, results in strongly alkaline solution	L -irritation of mucous membranes and lungs S -moderate A -moderate to high	Very caustic
Sodium Sulfide					1/500	Yellowish crystalline solid; sinks and dissolves freely, giving alkaline solution that liberates H_2S	L -irritant S -low (H_2S vapor hazard) A -low to high	--
Maleic Acid				1/32000		Colorless crystals; very soluble in water	L -very irritating to skin and respiratory tract S -low A -moderate	Combustable; protective clothing advisable

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, FLOATING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Benzene	20/4444	21/2913	18/684	19/1630	10/45504	Clear, colorless liquid; floats on water, slightly soluble	L -mild liquid and vapor irritant S -practically nontoxic, but large doses may be fatal A -high	Flammable; protective clothing and respirator advisable
Methyl Methacrylate				2/1000	1/2300	Clear colorless, volatile liquid; floats, slightly soluble	L -very irritating S -moderate A -moderate	Flammable; respirator and protective clothing advisable
Styrene	14/5561	17/15694	19/4342	13/57211	13/34538	Clear, colorless, oily liquid; floats, very slightly soluble	L -liquid and vapor irritant S -low A -moderate to high	Combustible
Toluene	13/298	13/699	13/658	17/22512	6/4332	Clear, colorless liquid; floats, very slightly soluble	L -liquid and vapor irritant S -low A -moderate to high	Flammable
Chromium Salts (metals & insolubles)			2/1300	3/15200		White to blue solid	L -varying levels of irritation S -cumulative poison (liver damage), carcinogen A -high	
Ethyl Benzene			1/168	1/20		Colorless liquid; slightly soluble, floats	L -slightly irritating S -low A -moderate	
Glycol Salicylate			4/516			Colorless liquid; slightly soluble in water, floats		
Methyl Ethyl Ketone			3/134	1/100	1/100	Colorless liquid; soluble, floats in water	L -irritating to eyes, nose, throat S -moderate A -moderate	Flammable, possible flashback produced, protective clothing and respirator advisable

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, SINKING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetic Anhydride			1/10000			Very refractive liquid; sinks in water to form acetic acid, slowly	L -liquid/vapor violently irritating to eyes, mucous membranes, skin S -burns and corrodes tissue A -corrosive and toxic to all aquatic life	Fire hazard; burns readily
Acrylonitrile	1/20000		2/103100	2/1000		Volatile liquid; evaporates quickly, dissolves slowly	L -extremely irritating vapor S -moderate to high A -moderate to high (fish and plankton)	Explosive, flammable; respirator and protective clothing advisable
Bromine		2/1800	1/500			Heavy, volatile, liquid; sinks in water, dissolving gradually	L -vapor is highly irritative, liquid causes severe burns S -highly corrosive and toxic (inhalation or ingestion) A -highly toxic	Highly reactive (powerful oxidizer); respirator and protective clothing
Cresol	5/103	1	1	5/105	1	Clear liquid or crystalline solid; slightly soluble	L -strongly irritating; may burn skin S -low to moderate; rapidly absorbed through skin A -moderate to high	Protective clothing advisable
Epichlorohydrin			1/20000			Colorless, volatile, unstable liquid; practically insoluble, sinks	L -very irritating S -moderate to high; narcotic A -moderate to high, especially to benthos	Respirator and protective clothing

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, SINKING COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Methylene Chloride (Dichloromethane)		1/550			1/900	Colorless volatile liquid; slightly soluble, sinks	L -irritant, especially to eyes S -moderate to severe A -moderate to low	Nonflammable
Perchloroethylene (Tetrachloroethylene)			1/1009	1/30		Colorless liquid; practically insoluble in water, sinks	L - S -narcotic in high concentration A -no data	Nonflammable
Dichloropropane					2/6300	Colorless, stable, mobile liquid; sinks, very slightly soluble	L -irritant to eyes, skin, mucous membranes S -low A -moderate	Flammable
Methyl Parathion				1/40000		White powder or as 82% solution in xylene; slightly soluble in water	L -highly toxic by ingestion, inhalation S -or absorption A -high	Combustible, extremely flammable with xylene. Wear protective clothing and SCUBA
INSOLUBLE, FLOATING COMPOUNDS								
Xylene	24/55037	21/100349	16/189435	18/771	6/99	Clear, colorless, mobile liquid; insoluble	L -low to moderate S -low to moderate A -moderate	Flammable, respirator advisable

TABLE 6.5
INSOLUBLE, SINKING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Carbon Tetrachloride		2/50	1/7000			Colorless, volatile liquid; practically insoluble, sinks	L -may irritate skin S -very slightly toxic A -probably low, except for benthic organisms	Does not burn
Turpentine	1/200		1/200	3/20028	1/15	Yellowish, sticky solid, or oily liquid; insoluble in water, sinks	L -irritating to skin, mucous membranes S -kidneys, highly toxic if ingested A -moderate	Flammable, avoid contact with liquid
Napthalene	3/401	5/49	7/7765	6/18851		White, crystalline, volatile flakes; practically insoluble, sinks	L -may irritate skin S -low A -high	Combustible
PCB's				3/150	5/84	Colorless to amber, viscous liquid, relatively insoluble in water, sinks	L -strong irritant S -highly toxic A -high	Combustible; respirator and protective clothing
Trichloro-ethylene		3/411	1/1500			Mobile liquid, practically insoluble in water, sinks		
Chlordane				2/250	1/110	Viscous, amber liquid; insoluble in water, sinks	L -moderately irritating S -high A -high	Not flammable but may be combustable, protective clothing and respirator

TABLE 6.5
COMPOUNDS WHICH VIOLENTLY REACT WITH WATER

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetyl Chloride					1/500	Flammable liquid; violent reaction with water	L -extremely irritative to eyes, skin and mucous membranes S -extremely toxic (hydrocyanic acid) A -extremely toxic (hydrocyanic acid)	Respirator and protective clothing
Sulphuric Acid	23/45385	19/11713	7/40480	12/37768	12/24515	Dense oily liquid, colorless to dark brown; miscible with water, concentrated, reacts violently with water	L -extremely irritating vapor, liquid causes severe burns S -corrosive poison A -moderate to high	--

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Hydro-fluoric Acid		1/300	1/1500		1	Clear, colorless, mobile liquid; completely miscible with water	L -extreme irritation to eyes, skin, lungs S -high A -high to moderate	Cannot catch fire; wear respirator and protective clothing
Methyl Alcohol (Methanol)	3/251	2/1643	2/1260400			Clear, colorless, mobile liquid; miscible with water	L -may irritate; dries skin S -low, but high concentration may cause blindness A -low	Flammable
Nitric Acid		1/250			2/4001	Clear to light brown liquid	L -severe burns; vapor may cause total lung injury S -moderate to high A -moderate to high	Extremely caustic and reactive; wear respirator and protective clothing
Phenol	5/1328	6/13275	1/25000	1/50	3/123	Colorless to pink crystalline solid or fluid; sinks and dissolves readily	L -irritant, caustic to skin S -moderate to high (ingestion) A -high	Wear protective clothing
n-Propyl Alcohol				1/69000		Colorless liquid; completely miscible with water	L -practically none S -low A -moderate	Flammable
Sulfuric Acid	28/45385	19/11713	7/40480	12/57211	12/24515	Colorless to dark brown, dense, oily liquid; miscible with water, concentrated, reacts violently with water	L -extremely irritating vapor; liquid causes severe burns S -corrosive poison A -moderate	--

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Vinyl Acetate			4/135		1/2500	Colorless liquid; floats; liquid monomer is soluble solid polymer is insoluble	L -irritant; harmful vapor S -moderate A -moderate	Very flammable; respirator and protective clothing advisable
Acetic Acid	5/31080	2/1000	3/3010			Colorless liquid; completely miscible	L -irritating, burning vapors and concentrated solutions S -nontoxic if dilute A -nontoxic if dilute, concentrated solutions very damaging	
Aluminum Sulfate					1/1000000	Shiny white solid; sinks and dissolves readily, forming an acid solution	L -low S -low A -low to moderate	--
Ammonium Compounds (Combination) Nitrate & Sulfate	2/3225	7/832	1/6000	6/50100	1/150000	White solids; sinks and dissolves in water	L -low S -low A -low to moderate	--
Chlorine			3/500	5/1515	1/4000	Greenish yellow gas, or clear amber compressed, liquified gas; sinks in water, slightly soluble	L -powerful irritant to skin and lungs S -corrosive to lungs and respiratory system A -very corrosive; highly toxic	Respirator and protective clothing advisable

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Chromium Compounds Chromic Salts (CrN) Chromous Salts (CrCl)	2/50	2/72	2/1300	3/15200		White to blue solid, sinks and is soluble in water	L -varying levels of irritation S -cumulative poison (liver damage), carcinogen A -high	--
Copper Compounds Nitrate Sulfate		2/600	2/573	3/85	1/200	Blue crystalline solid, sinks in water and dissolves readily	L -skin irritant S -low to moderate A -highly toxic	--
Lead Compounds Acetate Arsenate Chloride Nitrate Sulfate Tetra ethyl		3/7003		1/1980		Most are white crystals; sink in water, varying solubility	L -irritate S -cumulative poison; moderate A -high	For tetraethyl only: wear respirator and protective clothing
Maleic Anhydride					1/1970	Colorless needles; floats, hydrolyzes slowly to maleic acid, very soluble	L -very irritating S -low A -moderate	Protective clothing advisable
Nitrogen Dioxide			1/2000			Reddish brown gas; liquid below 72°F; sinks and dissolves, forming nitric acid and oxide	L -severe burns; lung injury S -moderate to high Nitric Acid A -moderate to high *NO_2 gas, deadly poison	Respirator and protective clothing

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetone Cyanohydrin				1/2100		Floats and readily dissolves; readily decomposes to yield Hydrocyanic Acid (liquid and vapor--extremely toxic and explosive as a gas)	L -may slightly irritate eyes, skin, mucous membranes S -extremely toxic (as Hydrocyanic Acid) A -extremely toxic (as Hydrocyanic Acid)	Wear respirator, protective clothing
Ammonia	4/26005	7/101550		1/6000	7/2115	Colorless gas, dissolves readily in water, results in strong basic solution	L -very irritating to eyes and mucous membranes, somewhat irritating to skin S -slight A -high to moderate	Respirator and protective clothing advisable
Dimethylamine				1/4000		Colorless gas; liquifies at 45°F; soluble in water, resulting in strongly alkaline solution	L -skin burn S -low A -moderate	Very flammable
Ethyl Alcohol			1/30	1/42	1/6000	Clear, colorless liquid; completely miscible with water	L -none S -drunkeness A -low to moderate	Flammable, even when mixed with water
Ethylene Glycol	4/570			2/51	4/393654	Clear, colorless liquid; sinks and dissolves readily	L -none S -low A -low	Flammable
Hydrochloric Acid	10/16435	11/763115	6/4545	4/223	8/29150	Clear, colorless to slightly yellow liquid; miscible with water	L -Vapor--extreme irritation, liquid causes burns S -moderate A -moderate	Strongly Corrosive, Nonflammable

TABLE 6.5
HIGHLY SOLUBLE/MISCIBLE COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Potassium Permanganate			2/510			Dark purple crystals; sinks and dissolves	L -irritant S -low A -high (fish and algae)	--
Sodium Bisulfite			2/2000			White, crystalline solid; sinks and dissolves to form acid solution	L -may irritate skin S -low A -moderate to high	--
Sodium Hydroxide	14/4350	9/6184	18/60454	14/47267	52/5700	White solid; sinks, very soluble	L -powerful caustic; burns tissue S -corrosive poison A -moderate to high	Very corrosive; protective clothing advisable
Sodium Hypochlorite			2/2500		1/50	Highly unstable crystals, dissolve in water, results in strongly alkaline solution	L -irritation of mucous membranes and lungs S -moderate A -moderate to high	Very caustic
Sodium Sulfide					1/500	Yellowish crystalline solid; sinks and dissolves freely, giving alkaline solution that liberates H_2S	L -irritant S -low (H_2S vapor hazard) A -low to high	--
Maleic Acid				1/32000		Colorless crystals; very soluble in water	L -very irritating to skin and respiratory tract S -low A -moderate	Combustable; protective clothing advisable

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, FLOATING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Benzene	20/4444	21/2913	18/684	19/1630	10/45504	Clear, colorless liquid; floats on water, slightly soluble	L -mild liquid and vapor irritant S -practically nontoxic, but large doses may be fatal A -high	Flammable; protective clothing and respirator advisable
Methyl Methacrylate				2/1000	1/2300	Clear colorless, volatile liquid; floats, slightly soluble	L -very irritating S -moderate A -moderate	Flammable; respirator and protective clothing advisable
Styrene	14/5561	17/15694	19/4342	13/57211	13/34538	Clear, colorless, oily liquid; floats, very slightly soluble	L -liquid and vapor irritant S -low A -moderate to high	Combustible
Toluene	13/298	13/699	13/658	17/22512	6/4332	Clear, colorless liquid; floats, very slightly soluble	L -liquid and vapor irritant S -low A -moderate to high	Flammable
Chromium Salts (metals & insolubles)			2/1300	3/15200		White to blue solid	L -varying levels of irritation S -cumulative poison (liver damage), carcinogen A -high	
Ethyl Benzene			1/168	1/20		Colorless liquid; slightly soluble, floats	L -slightly irritating S -low A -moderate	
Glycol Salicylate			4/516			Colorless liquid; slightly soluble in water, floats		
Methyl Ethyl Ketone			3/134	1/100	1/100	Colorless liquid; soluble, floats in water	L -irritating to eyes, nose, throat S -moderate A -moderate	Flammable, possible flashback produced, protective clothing and respirator advisable

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, SINKING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetic Anhydride			1/10000			Very refractive liquid; sinks in water to form acetic acid, slowly	L -liquid/vapor violently irritating to eyes, mucous membranes, skin S -burns and corrodes tissue A -corrosive and toxic to all aquatic life	Fire hazard; burns readily
Acrylonitrile	1/20000		2/103100	2/1000		Volatile liquid; evaporates quickly, dissolves slowly	L -extremely irritating vapor S -moderate to high A -moderate to high (fish and plankton)	Explosive, flammable; respirator and protective clothing advisable
Bromine		2/1800	1/500			Heavy, volatile, liquid; sinks in water, dissolving gradually	L -vapor is highly irritative, liquid causes severe burns S -highly corrosive and toxic (inhalation or ingestion) A -highly toxic	Highly reactive (powerful oxidizer); respirator and protective clothing
Cresol	5/103	1	1	5/105	1	Clear liquid or crystalline solid; slightly soluble	L -strongly irritating; may burn skin S -low to moderate; rapidly absorbed through skin A -moderate to high	Protective clothing advisable
Epichlorohydrin			1/20000			Colorless, volatile, unstable liquid; practically insoluble, sinks	L -very irritating S -moderate to high; narcotic A -moderate to high, especially to benthos	Respirator and protective clothing

TABLE 6.5
SLIGHTLY SOLUBLE/DISSOLVES SLOWLY, SINKING COMPOUNDS (Continued)

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Methylene Chloride (Dichloromethane)		1/550			1/900	Colorless volatile liquid; slightly soluble, sinks	L -irritant, especially to eyes S -moderate to severe A -moderate to low	Nonflammable
Perchloroethylene (Tetrachloroethylene)			1/1009	1/30		Colorless liquid; practically insoluble in water, sinks	L - S -narcotic in high concentration A -no data	Nonflammable
Dichloropropane					2/6300	Colorless, stable, mobile liquid; sinks, very slightly soluble	L -irritant to eyes, skin, mucous membranes S -low A -moderate	Flammable
Methyl Parathion				1/40000		White powder or as 82% solution in xylene; slightly soluble in water	L -highly toxic by ingestion, inhalation S -or absorption A -high	Combustible, extremely flammable with xylene. Wear protective clothing and SCUBA
INSOLUBLE, FLOATING COMPOUNDS								
Xylene	24/55037	21/100349	16/189435	18/771	6/99	Clear, colorless, mobile liquid; insoluble	L -low to moderate S -low to moderate A -moderate	Flammable, respirator advisable

TABLE 6.5
INSOLUBLE, SINKING COMPOUNDS

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Carbon Tetrachloride		2/50	1/7000			Colorless, volatile liquid; practically insoluble, sinks	L -may irritate skin S -very slightly toxic A -probably low, except for benthic organisms	Does not burn
Turpentine	1/200		1/200	3/20028	1/15	Yellowish, sticky solid, or oily liquid; insoluble in water, sinks	L -irritating to skin, mucous membranes S -kidneys, highly toxic if ingested A -moderate	Flammable, avoid contact with liquid
Napthalene	3/401	5/49	7/7765	6/18851		White, crystalline, volatile flakes; practically insoluble, sinks	L -may irritate skin S -low A -high	Combustible
PCB's				3/150	5/84	Colorless to amber, viscous liquid, relatively insoluble in water, sinks	L -strong irritant S -highly toxic A -high	Combustible; respirator and protective clothing
Trichloroethylene		3/411	1/1500			Mobile liquid, practically insoluble in water, sinks		
Chlordane				2/250	1/110	Viscous, amber liquid; insoluble in water, sinks	L -moderately irritating S -high A -high	Not flammable but may be combustable, protective clothing and respirator

TABLE 6.5
COMPOUNDS WHICH VIOLENTLY REACT WITH WATER

Material	No. of Spills/Total Gallons					Physical Description	Toxicity (L-local, S-systemic; A-aquatic)	Hazard
	1976	1977	1978	1979	1980			
Acetyl Chloride					1/500	Flammable liquid; violent reaction with water	L -extremely irritative to eyes, skin and mucous membranes S -extremely toxic (hydrocyanic acid) A -extremely toxic (hydrocyanic acid)	Respirator and protective clothing
Sulphuric Acid	23/45385	19/11713	7/40480	12/37768	12/24515	Dense oily liquid, colorless to dark brown; miscible with water, concentrated, reacts violently with water	L -extremely irritating vapor, liquid causes severe burns S -corrosive poison A -moderate to high	--

Because of the limited scope of this paper, not all compounds spilled in amounts greater than 42 gallons are listed. Compounds that have low human and aquatic toxicity or were not spilled frequently and in large volumes are not shown.

As indicated in Table 6.5, the variety of materials and their properties is quite large. The decision as to when and how to use divers/ROV's in response to releases of these chemicals will necessarily involve many considerations.

Table 6.6 makes a comparison of priority hazardous substances that are encountered in the water environment.

Source and Cause of Spills

The functions a diver/ROV will perform in response to spills will depend not only on the material and its properties but also on the source of the spill and its related cause. This section briefly discusses some of the major sources and causes of both petroleum spills and hazardous chemical spills.

The following list shows the various sources and numbers of spills of hazardous chemicals during the period 1977 through 1980 in the same format as that for petroleum spills.

Source	Number of Spills
Vessels (total)	133
- Tank ship	35
- Tank barge	77
- Other	21
Marine Facility	61
Vehicle Transportation	30
Transportation-Related Facility	16
Transportation Pipeline (total)	8
- Offshore Pipeline	0
Non-transportation-Related Facility (total)	168
- Offshore Production Platform	0
Miscellaneous	48

The breakdown of sources above is very significant in terms of diver/ROV response. Spills from vessels account for about 29 percent of the total number of spills, and another 13 percent are at marine facilities (port or harbor). As indicated, the majority of spill sources are the non-transportation-related facilities (primarily storage, production, and processing facilities).

TABLE 6-6

COMPARISON OF PRIORITY HAZARDOUS SUBSTANCES IN WATERWAYS

U.S. COAST GUARD POLLUTION INCIDENT DATA BASE

- Acetic Acid
- Acetic Anhydride
- Acetone Cyanohydrin
- Acetyl Chloride
- Acrylonitrile
- Aluminum Sulfate
- Ammonia
- Ammonium Compound (Nitrate & Sulfate)
- Benzene
- Bromine
- Carbon Tetrachlorine
- Chlordane
- Chlorine
- Chromium Compounds
  - (Chromic Salts (CrN) & Chromous Salts (CrCl))
- Chromium Salts (metals & Insolubles)
- Copper Compounds (Nitrate & Sulfate)
- Cresol
- Dichloropropane
- Dimethylamine
- Epichlorohydrin
- Ethyl Alcohol
- Ethyl Benzene
- Ethylene Glycol
- Glycol Salicylate
- Hydrochloric Acid
- Hydrofluoric Acid
- Lead Acetate
- Lead Arsenate
- Lead Chloride
- Lead Nitrate
- Lead Sulfate
- Lead Tetraethyl
- Lead
- Maleic Acid
- Maleic Anhydride
- Methyl Alcohol (Methanol)
- Methyl Ethyl Ketone
- Methyl Methacrylate
- Methyl Parathion
- Methylene Chloride (Dichloromethane)
- Napthalene
- Nitric Acid
- Nitrogen Dioxide
- Perchloroethylene (Tetrachloroethylene)
- Phenol
- Polychlorinated Biphenyls (PCB)
- Potassium Permanganate
- n-Propyl Alcohol
- Sodium Disulfite
- Sodium Hydroxide
- Sodium Hypochlorite
- Sodium Sulfide
- Styrene
- Sulfuric Acid
- Toluene
- Trichloroethylene
- Turpentine
- Vinyl Acetate

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- Acetyl Chloride
- Acrylonitrile
- Aqueous Film Forming Foam
- Benzene
- 1,2-Butylene Oxide
- Chlorine
- Carbon Disulfide
- Diethylether
- DS-2
- Ethylamine
- Ethylene Glycol
- Ethyl Methacrylate
- Formaldehyde
- Formic Acid
- Hexane
- Hydrochloric Acid
- Methyl Ethyl Ketone
- Nitrobenzene
- Oil, Gasoline
- Oil, JP-4
- Organo-Tin Paint
- Polychlorinated Biphenyls
  - (50% Solution with Trichlorobenzene)
- Sulfuric Acid
- Super Tropical Bleach
- Trichloroethylene

NOAA HAZARDOUS MATERIALS RESPONSE PROJECT

- Acetone
- Ammonia
- Ammonium Nitrate
- Anyhdrous Ammonia
- Benzene
- Butyraldehydes
- Dichloromethane (Methylene Dichloride)
- Ethanol (Ethyl Alcohol)
- Hydrochloric Acid (Muriatic Acid)
- Isopropanol (Isopropyl Alcohol)
- Methanol (Methyl Alcohol, wood alcohol)
- Methyl Ethyl Ketone (MEK)
- Methyl Parathion
- Perchloroethylene (Tetrachloroethylene)
- Phenol
- Phosphoric Acid
- Propane (Liquified Propane Gas)
- Sodium Hydroxide (Caustic Soda)
- Styrene (Vinyl Benzene)
- Sulfuric Acid (Oleum, Oil of Vitriol)
- Tetraethyl Lead
- Toluene (Methyl Benzene)
- Xylenes

ENVIRONMENT CANADA

- Acetic Acid
- Acetic Anhydride
- Ammonia
- Ammonium Nitrate
- Ammonium Phosphate
- Benzene
- Calcium Chloride
- Calcium Oxide/Hydroxide
- Carbon Dioxide
- Chlorine
- Cyclohexane
- Ethylbenzene
- Ethylene Dichloride
  - (1,2-Dichloroethane)
- Ethylene Glycol
- Ethylene Oxide
- Ethylene
- Ferric Chloride
- Formaldehyde
- Hydrogen Chloride/Acid
- Hydrogen Fluoride/Acid
- Hydrogen Sulfide
- Mercury
- Methanol
- Morpholine
- Naphtha
- Natural Gas
- Nitric Acid
- Phenol
- Phosphoric Acid
- Phosphorous
- Potash (Potassium Chloride)
- Propylene Oxide
- Propylene
- Sodium Chlorate
- Sodium Chloride
- Sodium Hydroxide
- Sodium Hypochlorite
- Sodium Sulfate
- Styrene (Monomer)
- Sulfur Dioxide
- Sulfuric Acid (and Oleum)
- Sulfur
- Tetraethyl Lead
- Toluene
- Urea
- Vinyl Chloride
- Xylenes
- Zinc Sulfate
- 2-Ethylhexanol

The causes of these spills are more varied than those with petroleum spills. Tank overflows are the most frequent cause, regardless of the source. The second most common cause is, once again, pipeline or hose ruptures and leaks. Leaks from the hulls or tank compartments of vessels as a result of grounding or collision was the third leading cause with 25 incidents. Other causes include various equipment failures, improper handling of equipment, personnel error, and unknown causes.

"Typical" Spill Environment

The foregoing analysis has provided the information necessary to draw conclusions and make certain assumptions about the types of spill environment in which divers/ROV's would most commonly be placed in response to spills. The following is a summary of the range of typical spill site conditions. These conditions will apply to both petroleum and hazardous chemical spills unless otherwise noted.

Location of Spills

Based on our previously determined criteria (spill volume and exclusion of beaches/non-navigable), the distribution of spills requiring underwater activity will be based on where the largest number of spills occur. Rivers, primarily the Mississippi and all of its tributary systems, and ports and harbors serving the inland areas and the Atlantic and Gulf coasts, will undoubtedly be the most common waterbodies to receive spills.

This fact is very significant because these areas allow the most immediate and direct pollutant exposure to large concentrations of people through (1) contact recreation, (2) drinking water supplies, (3) bioaccumulation of toxics in fish and shellfish harvested from rivers, and (4) occupational exposure. Spills into open coastal waters, while potentially serious, will not occur as often and probably will not be complicated by the intense human contact present in rivers, ports, and harbors.

Depth

The full range could be from a few feet to several hundred feet. An assumption of 20 to 100 feet would be appropriate for typical spill areas.

Currents

A current in these areas can almost always be expected. Occasionally, it will complicate diving operations and be a major factor in dispersal of a spilled compound. Currents could become severe in an area that is flow restricted (e.g., narrow channel). A current of 0.5 to 3 knots would be common. Up to 7-8 knots are possible in certain areas. In areas of tidal currents, pollutant transport and dispersal monitoring will become complicated.

Underwater Visibility

The areas identified in the "Location of Spills" section are known for their murkiness and lack of visibility. Zero visibility will undoubtedly be common and is a critical and limiting factor in performing underwater activity in a chemically-contaminated environment. Spills in open coastal waters and the Great Lakes will likely have better visibility.

Bottom Conditions

Mud will be the most common substrate. Some coastal ports and harbors may have sand or sand/rock bottoms. Open coastal spills will probably have sand bottoms. In most of these areas, especially ports and harbors, a great deal of debris and junk will often be littering the bottom. Diver/ROV entanglement or tearing of a suit is a potential problem.

Sea State

Only a fraction of one percent of the spills occur in the open ocean (outside of bays, estuaries, sounds, etc.). Since almost all spills occur in protected waters, the sea state will rarely exceed six to eight feet. Rough seas will be important when considering effective and safe surface support activities and underwater surge. Rough seas could be a limiting factor for underwater activity.

Shore Facilities Available

Since most spills occur in or near major shipping areas, a wide range of shore and marine facilities will usually be convenient to the spill site. This is significant in terms of being able to respond rapidly with equipment and personnel. Problems encountered with equipment or divers/surface support persons can also be addressed more quickly with shore facilities close at hand. Another factor is that many spills occur at the dock or terminal during loading and unloading procedures.

The above conditions typify the more common spill environment. These typical spill environments also offer some of the most difficult problems spill response teams will face. Exposure of the general public, potential contamination of public water supplies, currents, poor visibility, bottom substrate and debris, and other factors indicate the seriousness of these spills both from a public health viewpoint and the difficulty encountered in diver/cleanup, personnel protection. Spills in open coastal waters will probably be more easily addressed in many instances but, as indicated, there are few spills in these areas.

SECTION 7

HAZARDOUS SUBSTANCES

INTRODUCTION

At an incident, response personnel may be exposed to a number of substances that are hazardous because of their chemical, biological, or radiological characteristics.

Radiological hazards present a problem for response personnel. Radioactive materials can emit alpha or beta particles or gamma waves, all of which can have a harmful effect on health if workers are exposed to excessive amounts.

Biological agents are living organisms (or their products) that can cause sickness or death to exposed individuals.

Chemical hazards are classified into several groups, including fire, toxic, corrosive, and reactive hazards. A material may generate more than one chemical hazard during an incident, for example, toxic vapors can be released during chemical fires. The hazards can be a result of the physical /chemical properties of a material or of its chemical reactivity with other materials or the environment to which it is exposed.

Many hazards may be present at any one incident. It is important to understand the fundamentals of each and their relationships so that effective safety practices may be employed to reduce the risk to the public and response personnel.

BIOLOGICAL HAZARDS

Biological hazards can cause infection or disease in persons who are exposed. Biological hazards may involve plants or animals including microorganisms. They are divided into five categories: viral, rickettsial/ chlamydial, bacterial, fungal, and parasitic.

Biological hazards, such as disease-causing agents, may be present at a hazardous waste site or involved in a spill. Like chemical hazards, they may be dispersed throughout the environment via wind and water.

Many biological agents require a carrier to inoculate a host. Hence, controlling the agent may require controlling the carrier. For instance, rabid rodents at a landfill may be a biological hazard. Rocky Mountain Spotted Fever, which is carried by ticks, is also in this category.

The same personel protective requirements of a response to a chemical hazard apply to biological hazards. Body coverings and respiratory protetive equipment should be utilized. Especially important is the need to maintain personal cleanliness. Showering after removing protective clothing and thoroughly washing exposed body parts, including hands and face, should help remove any residual contamination.

RADIATION HAZARDS

Radioactive materials that may be encountered at a site can emit three types of harmful radiation: alpha particles, beta particles, and gamm waves. All three forms harm living organisms by imparting energy which ionizes molecules in the cells. Hence, the three are referred to as ionizing radiation. Ionization may upset the normal cellular function, causing disfunction or death.

An alpha particle is postively charged. The beta is an electron possessing a negative charge. Both particles have mass and energy. Both are emitted from the nucleus. They travel short distances in material before interactions with the material causes them to lose their energy. The outer layers of the skin and clothing generally protect against these particles. Therefore, they are considered hazardous primarily when they enter the body through inhalation or ingestion.

Gamma radiation is pure electromagnetic energy and is wavelike, rather than particulate, in nature. Gamma waves pass through all materials to some degree. Clothing, including protective gear, will not prevent gamma radiation from interacting with body tissue.

Unlike many hazards that possess certain properties to alert response personnel (odor, irritation, or taste), radiation does not warn. Hence, preventing the radioactive material from entering the body or protecting against external radiation is the best protection. As with biological and chemical hazards, the use of respiratory and personnel protective equipment, coupled with scrupulous personal hygiene, will afford good protection against particulate radiation.

CHEMICAL HAZARDS

Fire Hazards

Combustibility--

Combustibility is the ability of a material to act as a fuel, that is, to burn. Materials that can be readily ignited and sustain a fire are considered to be combustible, while those that do not are called noncombustible. Three elements are required for combustion to occur: fuel, oxygen, and heat. The concentration of the fuel and the oxygen must be high enough to allow ignition and maintain the burning process. Combustion is a chemical reaction that requires heat to proceed:

$$\text{fuel} + \text{oxygen} \xrightarrow{\text{heat}} \text{products}$$

Heat is supplied by the ingition source and is maintained by the combustion, or it must be supplied from an external source. The relationship of these three fire components is illustrated as a triangle in Figure 7.1. Most fires can be extinguished by removing one of these components. For example, water applied to a fire removes the heat, thereby extinguishing the fire. when a material by itself generates enough heat to self-ignite and combust, spontaneous combustion occurs, either as a fire or explosion.

Flammability--

Flammability is the ability of a material (liquid or gas) to generate a sufficient conentration of combustible vapors under normal conditions to be ignited and produce a flame. It is necessary to have a proper fuel-to-air (oxygen) ration (% fuel in air) to allow combustion. There is a range of fuel concentrations in air for each material where it can be ignited and sustain combustion. This is called the Flammable Range. The lowest concentratjion of fuel in this range is the Lower Flammable Limit (LFL). Concentrations less than the LFL are not flammable because there is too little fuel - that is, the mixture is too "lean". The highest ration that is flammable is the Upper Flammable Limit (UFL). Concentrations greater than the UFL are not flammable because there is too much fuel displacing the oxygen (or too little oxygen). This mixture is too "rich". Fuel concentrations between the LFL and UFL are optimum for starting and sustaining fire. Example: The LFL for benzene is 1.3% (13,000 ppm), the UFL is 7.1% (71,000 ppm), thus the flammable range is 1.3% to 7.1%.

A flammable material is considered highly combustible if it can burn at ambient temperatures (68°F). But a combustible material is not necessarily flammable, because it may not be ignited easily or the ignition maintained. Pyrophoric materials will ignite at room temperature in the presence of a gas or vapor or when a slight friction or shock is applied.

Note: The U.S. Department of Transportation (DOT), the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the National Fire Protection Association (NFPA) have established strict definitions for flammability based on the flash point of a material.

Gas or Vapor Explosions--

A gas or vapor explosion is a very rapid, violent release of energy. If combustion is extremely rapid, large amounts of kinetic energy, heat, and gaseous products are released. The major factor contributing to the explosion is the confinement of a flammable material. When vapors or gases cannot freely dissipate, they enter the combustion reation more rapidly. Confinement also increases the energy associated with these molecules, which enhances the explosive process. Poorly ventilated buildings, sewers, drums, and bulk liquid containers are examples of places where potentially explosive atmospheres may exist.

Explosive gases/vapors exhibit an explosive range, which is the same as the flammable range. The upper explosive limit (UEL) and lower explosive limit (LEL) are the UFL and LFL but in confined areas. Most reference books list either limits or flammable limits which are identical.

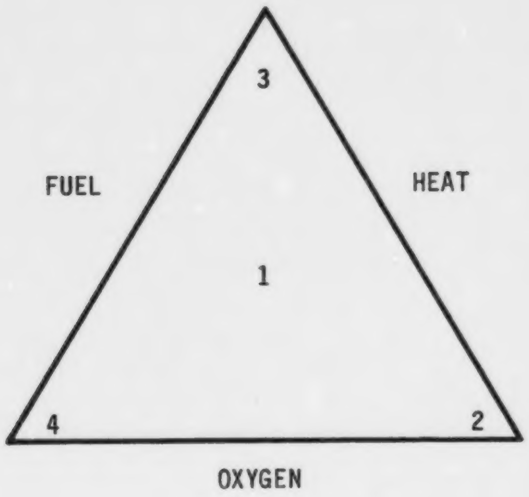


Figure 7.1. The fire triangle. Each side of the triangle represents one of the necessary elements of a fire. The optimum situation, position number 1, is the best fuel-to-oxygen ratio, with sufficient heat to ignite the fuel and support its combustion. Each corner illustrates the removal of one component: in number 2 there is insufficient fuel (concentrations below the Lower Flammable Limit), in number 3 there is not enough oxygen (concentrations above the Upper Flammable Limit), and in number 4 the heat source is not adequate. A fire can be defined as a self-sustaining, flaming combustion.

Summary: Practical Considerations--

Fires and explosions require fuel, air (oxygen), and an ignition source (heat). At a hazardous materials incident, the first two are not easily controlled. Consequently, while working on-site where a fire hazard may be present, the concentration of combustible gases in air must be monitored, and any potential ignition source must be kept out of the area.

Most dangerous flammable substances:

- are easily ignited (e.g., pyrophorics).
- require little oxygen to support combustion.
- have low LFL/LEL and a wide Flammable/Explosive range.

Hazards related to fires and explosions:

- physical destruction due to shock waves, heat, and flying objects
- initiation of secondary fires or creation of flammable conditions.
- release of toxic and corrosive compounds into the surrounding environment.

Explosive Hazards

Explosives--

An explosive is a substance which undergoes a very rapid chemical transformation, producing large amounts of gases and heat. The gases produced, for example, nitrogen, oxygen, carbon monoxide, carbon dioxide, and stream, due to the heat produced, rapidly expand at velocities exceeding the speed of sound. This creates both a shock wave (high pressure wave front) and noise (brisance).

Types of Explosive Hazards--

High or detonating--Chemical transformation occurs very rapidly with detonation rates as high as 4 miles per second. The rapidly expanding gas produces a shock wave which may be followed by combustion.

Primary high explosive: detonating wave produced in an extremely short period of time. May be detonated by shock, heat, or friction. Examples are lead azide, mercury fulminate, and lead styphnate.

Secondary high explosive: generally needs a booster to cause it to detonate. Relatively insensitive to shock, heat, or friction. Examples are tetryl, cyclonite, dynamite, and TNT.

Low or deflagrating--Rate of deflagration up to 1000 feet per second. Generally combustion followed by a shock wave. Examples are smokeless powder, magnesium, and Molotov cocktail.

Practical Considerations--

High or low does not indicate the explosion hazard (or power) but only the rate of chemical transformation.

Explosions can occur as a result of reactions between many chemicals not ordinarily considered as explosives. Ammonium nitrate, a fertilizer, can explode under the right conditions. Alkali metals and water explode; as will water and peroxide salts. Picric acid and certain ether compounds become highly explosive with age. Gases, vapors, and finely divided particulates, when confined, can also explode if an ignition source is present.

Toxic Hazards

Toxicity--

Toxic materials cause local or systemic detrimental effects in an organism. Exposure to such materials does not always result in death, although that is often the most immediate concern. Types of toxic hazards can be categorized by the physiological effect they have on the organism. A material may induce more than one physiological response.

Types of Toxic Hazards--

Systemic poisons--Systemic poisons are chemical agents which act on specific target organs or organ systems (Table 7.1). A subgroup includes anesthetics and narcotics, which may not be toxic in the classical sense because they do not necessarily cause irreversible harm. However, for response personnel, these agents can be extremely hazardous because they can impair judgment and the thought processes. Anesthetics and narcotics depress the central nervous system, resulting in loss of sensation or in stupor. If concentrations are great enough, coma and death can occur.

Asphyxiants--Asphyxiants are agents which deprive the tissues of oxygen, a condition called anoxia. This group is divided into simple and chemical asphyxiants (Table 7.2). The simple asphyxiants act by diluting or displacing atmospheric oxygen, which lowers the concentration of oxygen in air.

Breathing air with low oxygen concentration causes insufficient oxygen in blood and tissues. This can cause headache, unconsciousness, and eventually death. Inert gases can be simple asphyxiants.

Chemical asphyxiants act in one of two ways. Some prevent the uptake of oxygen in the blood. Carbon monoxide, for example, interferes with the transport of oxygen to the tissues by strongly binding with hemoglobin to form carboxyhemoglobin, which leaves inadequate hemoglobin available for oxygen transport.

A second type of chemical asphyxiant does not permit normal oxygen transfer either from the blood to the tissues or within the cell itself. Hydrogen cyanide is an example of this type.

A common, and extremely toxic, example of a compound that is both a chemical and simple asphyxiant is hydrogen sulfide. The chemical action, actually that of a neurotoxic systemic poison, stops oxidation of the respiratory issues, paralyzing the lungs. The result is that no air enters the lungs, which causes simple asphyxiation. Oxygen concentrations in the lungs drop, causing death.

TABLE 7.1. SYSTEMIC POISONS

Anesthetics/Narcotics	Compounds Damaging the Nervous System
Olefins	Methanol
Ethyl ether	Carbon disulfide
Isopropyl ether	Metals
Paraffinic hydrocarbons	Organometallics
Aliphatic ketones	
Aliphatic alcohols	Compounds Damaging Liver Function
Esters	
	Carbon tetrachloride
	Tetrachloroethane
Compounds Damaging Kidney Function	Compounds Damaging Blood-Circulatory System
Halogenated hydrocarbons	Aniline
	Toluidine
	Nitrobenzene
	Benzene
	Phenols

TABLE 7.2. ASPHYXIANTS

Simple Asphyxiants	Chemical Asphyxiants
Aliphatic hydrocarbons	Aniline
Helium	Methyl aniline
Nitrogen	Cyanogen
Hydrogen	hydrogen cyanide
Nitrous oxide	Toluidine
Carbon dioxide	Carbon monoxide
Methane	

Irritants--Irritants are materials that cause inflammation of membranes. The mechanism of irritation is either by corrosive or drying action, and may affect the eyes, skin, respiratory membranes, or gastrointestinal tract. The irritant must come in direct contact with tissue to cause an inflammation reaction. Consequently, skin, eye, and respiratory irritants are the greatest concern for response personnel (Table 7.3).

TABLE 7.3. IRRITANTS

Skin Irritants	Respiratory Irritants
Acids	Aldehydes
Alkalies	Ammonia
Solvents	Hydrogen chloride
Metallic salts	Ozone
Detergents	Nitrogen dioxide

Skin exposure to irritating materials, in high enough concentrations, may result in contact dermatitis, characterized by redness, itching, and drying of the skin. These dermatitis-causing materials are called primary irritants. Organic solvents are examples of primary irritants, eliciting a response in hours. Strong (or absolute) irritants are the acids and alkalies, producing observable effects within minutes. Extremely corrosive agents can cause skin ulceration and destroy tissues.

If respiratory tissues are insulated by irritant gases or fumes, they constrict in a reflex fashion, accompanied by involuntary coughing. Tracheitis and bronchitis are inflammations of the major air passages. Examples of irritant gases are chlorine, ammonia, ozone, and sulfur dioxide. More insidious irritating agents can reach the terminal respiratory passages (alveoli) deep in the lungs and may result in pulmonary edema, pneumonia, and eventually death.

It is important to note that many particulates such as dusts, although not chemically active hazards, can be severly irritating.

Allergic Sensitizers--A sensitization to a chemical involves immune mechanisms. When a foreign substance called an antigen enters body tissue, it triggers production of antibodies, which react with the antigen to make it innocuous. Upon first exposure to a specific chemical, there are no antibodies in the body. After subsequent exposures, the concentration of antibodies increases until a threshold is reached. At this point, the antibody level is high enough so that upon exposure to the chemical, the antigen-antibody reaction, also called an allergic reaction, is severe enough to manifest itself in one or more symptoms. The body has become "sensitized" to that chemical.

Skin and respiratory sensitizers may show the same symptoms as irritants (for example, dermatitis, bronchitis, and conjunctivitis) and can range from discomfort from poison ivy to a fatal reaction from isocyanates (Table 7.4).

TABLE 7.4. ALLERGIC SENSITIZERS

Skin Sensitizers	Respiratory Sensitizers
Poison ivy	Sulfur dioxide
Poison oak	Isocyanates
Epoxy monomers	
Nickel	
Formaldehyde	
Toluene di-isocyanate	

Mutagens, Teratogens, and Carcinogens--An agent that can cause cancer in an organism is called a carcinogen. Cancer occurs in the organism exposed to the carcinogen. This differs from a mutagen, which changes a gene in a sperm or egg cell of the parent. The parent is not affected, but the offspring suffer the consequences. Teratogenesis is also manifested in offspring but differs from mutagenesis in that if results from exposure of the embryo or fetus to the agent itself. While some teratogens and carcinogens have been identified, it is not possible to accurately "pinpoint" mutagens because of the difficulty in observing mutagenic action in cells. Table 7.5 lists some teratogens and classes of carcinogens.

TABLE 7.5. CARCINOGENS AND TERATOGENS

Carcinogens	Teratogens
Halogenated hydrocarbons	Diethylstilbestrol (DES)
Polynuclear aromatics	Thalidomide
Aromatic amines	

Routes of Exposure--

There are only three pathways for substances to enter the body:

- Through contact with skin, eyes, and hair
- Inhalation
- Ingestion

The primary function of the skin is to act as a barrier against entry of foreign materials into the body. If this protective barrier is overcome, toxic chemicals enter. The barrier is greatly diminished by lacerations and abrasions. Also, many organic solvents greatly increase the permeability of the skin to materials that would otherwise not pass through it. Another factor is that the skin provides a large surface area for contact with toxic agents.

Inhalation is the most rapid route, immediately introducing toxic chemicals to respiratory tissues and the bloodstream. Once admitted to the blood through the lungs, these chemicals are quickly transported throughout the body to contact all of the organs.

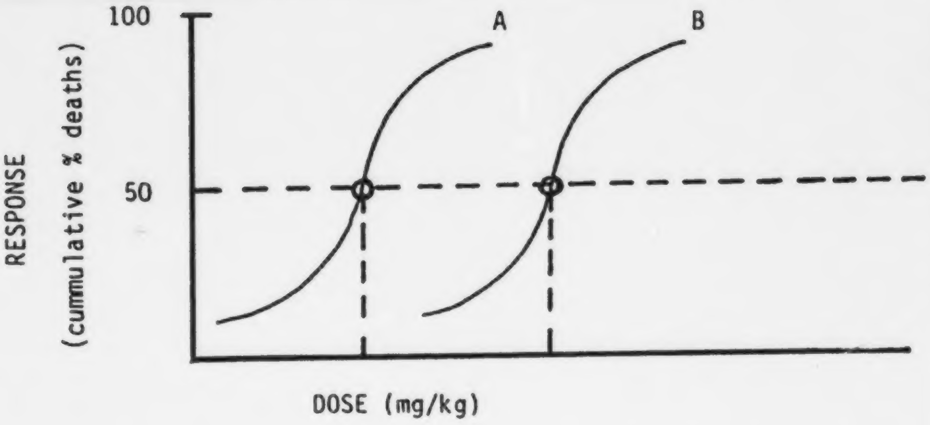
Health hazards to personnel from ingestion of materials are a lesser concern than skin and respiratory hazards. The number of substances that can be ingested are limited--that is, it is difficult to swallow vapors and gases. Also, ingestible materials only get to the mouth through hand-to-mouth contact. Even then, toxicity by mouth is of a lower order because of the acids, alkalies, and enzymes in the gastrointestinal tract. But these same conditions may enhance the toxic nature of a compound. While ingestion of toxic chemicals is not a great concern on-site, studies have shown that gum and tobacco chewers can absorb significant amounts of gaseous substances during an 8-hour day.

Measurement of Toxicity--

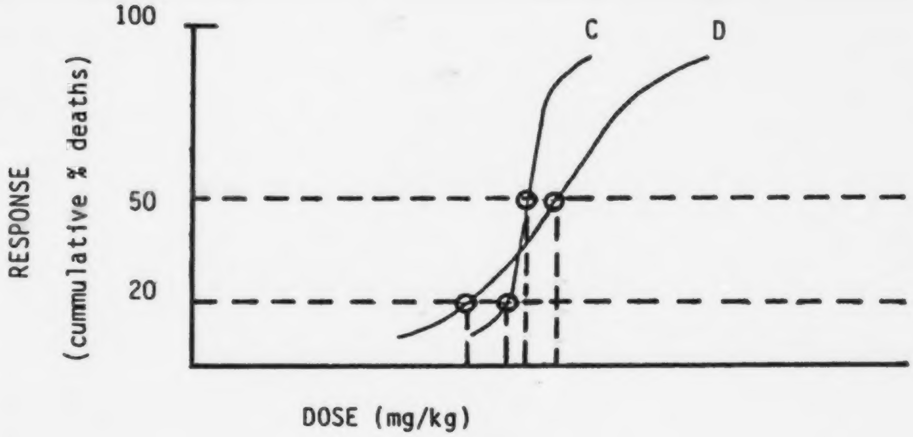
Generally, a given amount of a toxic agent will elicit a given type and intensity of response. Called a dose-response relationship, it is the basic for measurement of the relative harmfulness of a chemical. Because humans cannot be used as test organisms, almost all toxicological data are derived from other mammalian species, and results are extrapolated to humans. The test organism is chosen for its ability to simulate human response. For example, most skin tests are performed on rabbits because their skin response most closely resembles that of humans.

In much toxicological testing, the response measured is death. The test data are plotted on a dose-response curve. From this curve the dose, measured in milligrams (mg) of test agent per kilogram (kg) body weight of test organism, that killed a certain percentage of test organisms can be calculated. This dose is called the lethal dose. Most often, experiments are designed to measure the dose that kills 50% of the test organisms. This is the lethal dose 50, or LD_{50}, and is a relative measurement of toxicity. If compound A has an LD_{50} = 1000 mg/kg and compound B has an LD_{50} = 500 mg/kg, compound B is more toxic than compound A at that dose (Figure 7.2). A value similar to the LD_{50} used for inhalation exposures is the lethal concentration 50, or LC_{50}, and is measured as parts per million of toxic agent per exposure time (ppm/hr). Table 7.6 illustrates the use of LD_{50} values as a relative index of toxicity.

Another important factor to consider when determining the toxicity of a material is the relationship between concentration and exposure time. Generally, and an acute exposure refers to a large single dose received over a short period of time. A chronic exposure is several small doses over a longer period of time. The difference (in terms of deleterious effects) is that a small acute exposure may result in no effect on an organism, while a chronic exposure to the same dose may show an additive effect; that is, the cumulative dose may be harmful. On the other hand, a large single dose in a short period of time might be much more hazardous than the same dose administered over a longer time.



This illustration indicates that compound A is more toxic than B; that is, A gives the same response (50% deaths) as B at a lower dose.



From this illustration, compound C could be assumed to be more toxic than compound D, based on LD_{50}. This could be misleading because at lower doses the situation is reversed: at LD_{20}, D is more toxic than C.

FIGURE 7.2. DOSE - RESPONSE CURVES

The rate at which a chemical reaction occurs depends on the following factors:

- Surface area of reactants available at reactions site -- for example, a large chunk of coal is combustible, but coal dust is explosive.
- Physical state of reactant - solid, liquid, or gas
- Concentration of reactants
- Temperature
- Pressure
- Presence of a catalyst

TABLE 7.6. RELATIVE INDEX OF TOXICITY

	Probable Oral Lethal Dose for Humans	
Toxicity Rating or Class	Dose	For Average Adult
1. Practically nontoxic	>15 g/kg	More than 1 quart
2. Slightly toxic	5-15 g/kg	Between pint and quart
3. Moderately toxic	0.5-5 g/kg	Between ounce and pint
4. Very toxic	50-500 mg/kg	Between teaspoonful and ounce
5. Extremely toxic	5-50 mg/kg	Between 7 drops and teaspoonful
6. Supertoxic	>5 mg/kg	A taste (less than 7 drops)

Source: Toxicology: The Basic Science Of Poisons, 2nd ed.
Casarret and Doull (eds.), 1975.

Compatibility--

If two or more hazardous materials remain in contact indefinitely without reaction, they are compatible. Incompatibility, however, does no necessarily indicate a hazard. For example, acids and bases (both corrosive) react to form salts and water, which may not be corrosive.

Many operations on waste or accident sites involve mixing or unavoidable contact between different hazardous materials. It is important to know ahead of time if such materials are compatible. If they are not, then any number of chemical reactions could occur. The results could range from the formation of an innocuous gas to a violent explosion. Table 7.7 illustrates what happens when some incompatible materials are combined.

The identity of unknown reactants must be determined by chemical analysis to establish compatibility. On the basis of their properties, a chemist then should be able to determine any chemical reactions resulting from mixing the reactants. Judging the compatibility of more than two reactants is very difficult and should be judged on a one-to-one basis.

Response personel who must determine compatibilities should refer to "A Method for Determining the Compantibility of Hazardous Wastes" (EPA 600/2-80-076), published by EPA's Office of Research and Development.

Sometimes the identity of a waste is impossible to ascertain due to money and time constraints. In this event, simple tests must be performed to determine the nature of the material or mixture. Tests such as pH, oxidation-reduction potential, and flash point are useful. In addition, very small amounts of the reactants may be carefully combined to determine compatibility.

Practical Considerations--

If materials are compatible, they may be stored together in bulk tanks or transferred to tank trucks for ultimate disposal. Bulk containment of wastes for transport requires only one chemical analysis, whereas one is required for each drum or container transported.

Compatibility information is also very important in evaluating an accident involving several different hazardous materials. The ultimate handling and treatment of the materials may be partially based on such information.

TABLE 7.7. HAZARDS DUE TO CHEMICAL REACTIONS (INCOMPATIBILITIES)

- Generation heat - e.g., acid and water
- Fire - e.g., hydrogen sulfide and calcium hypochlorite
- Explosion - e.g., picric acid and sodium hydroxide
- Toxic gas or vapor production - e.g., sulfuric acid and plastic
- Flammable gas or vapor production - e.g., acid and metal
- Formation of a substance with a greater toxicity that the reactants - e.g., chlorine and ammonia
- Formation of shock - or friction-sensitive compounds
- Pressurization of closed vessels - fire extinguisher
- Solubilization of toxic substances - e.g., hydrochloric acid and chromium
- Dispersal of toxic dusts and mists
- Violent polymerization - e.g., ammonia and acrylonitrile

Practical Considerations--

The most immediate concern for response personnel is how the health of site workers and the public can be protected. The following factors must be considered:

- What toxic agent is present?
- How will it enter the body?
- How will it affect the human body?
- How toxic is it?

Answers to these and related questions will dictate how the public is protected (e.g., a warning or evacuation of an area), how personnel are protected (types of respiratory and protective gear employed), and what monitoring (e.g., continuous or intermittent) is required.

Corrosive Hazards

Corrosion--

Corrosion is a process of material degradation. Upon contact, a corrosive material may destroy body tissues, metals, plastics, and other materials. Technically, corrosivity is the ability of material to increase the hydrogen ion or hydronium ion concentration of a material, or to transfer electron pairs to or from itself or another material. A corrosive material is a reactive compound or element that produces a destructive chemical charge in the material it is acting upon. Common corrosives are the halogens, acids, and bases (Table 7.8). Skin irritation and burns are typical results when the body contacts an acidic or basic material.

The corrosiveness of acids and bases can be compared on the basis of their ability to dissociate (form ions) in solution. Those that form the greatest number of hydrogen ions (4^+) are the strongest acids, while those that form the most hydroxide ions (OH^-) are the strongest bases. The H^+ ion concentration in solution is called pH. Strong acids have a low pH (many H^+ in solution), while strong bases have a high pH (few H^+ in solution; many OH^- in solution). The pH scale ranges from 0 to 14 as follows:

<--- increasing acidity   neutral   increasing basicity--->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH Measurements are valuble because they can be done quickly on-site, providing immediate information about the corrosive hazard.

TABLE 7.8. CORROSIVES

Halogens	Acids
Bromine	Acetic acid
Chlorine	Hydrochloric acid
Fluorine	Hydrofluoric acid
Iodine	Nitric acid
Oxygen (ozone)	Sulfuri acid
Bases (Caustics)	
Potassium hydroxide	
Sodium hydroxide	

Practical Considerations--

When dealing with corrosive materials in the field, it is imperative to determine:

- How toxic is the corrosive material? Is it an irritant or does it cause severe burns?
- What kind of structural damage does it do, and what other hazards can it lead to? For example, will it destroy containers holding other hazardous materials, releasing them to the environment?

Hazards Due to Chemical Reactivity

Reactivity Hazards--

A reactive material is one that can undergo a chemical reaction under certain specified conditions. Generally, the term "reactive hazard" is used to refer to a substance that undergoes a violent or abnormal reaction in the presence of water or under normal ambient atmospheric conditions. Among these types of hazards are the pyrophoric liquids which will ignite in air at or below normal room temperature in the absence of added heat, shock, or friction, and the water-reactive flammable solids which will spontaneously combust upon contact with water (Table 7.9).

Chemical Reactions--

A chemical reaction is the interaction of two or more substances, resulting in chemical changes. Exothermic chemical reactions, which give off heat, can be the most dangerous. A separate source of heat is required to maintain endothermic chemical reactions. Removing the heat source stops the reaction.

Chemical reactions usually occur in one of the following ways:

- Combination	A + B --> AB
- Decomposition	AB --> A + B
- Single replacement	A + BC --> B + AC
- Double replacement	AB + CD --> AD + CB

TABLE 7.9. FLAMMABLE COMPOUNDS AND ELEMENTS

Flammable Liquids	Flammable Solids
Aldehydes	Phosphorus
Ketones	Magnesium dust
Amines	Zirconium dust
Ethers	Titanium dust
Aliphatic hydrocarbons	Aluminum dust
Aromatic hydrocarbons	Zinc dust
Alcohols	
Nitroaliphatics	
Water-Reactive Flammable Solids	**Pyrophoric Liquids**
Potassium	Organometallic compounds
Sodium	Dimethyl zinc
Lithium	Tributyl aluminum

Physical Properties of Chemicals

Chemical compounds possess inherent properties which determine the type and degree of the hazard they represent. Evaluating risks of an incident depends on understanding these properties and their relationship to the environment.

Solubility--

The ability of a solid, liquid, gas, or vapor to dissolve in a solvent is solubility. An insoluble substance can be physically mixed or blended in a solvent for a short time but is unchanged when it finally separates. The solubility of a substance is independent of its density or specific gravity.

The solubility of a material is important when determining its reactivity, dispersion, mitigation, and treatment. Solubility is generally given in parts per million (ppm).

Density/Specific Gravity--

The density of a substance is its mass per unit volume, commonly expressed in grams per cubic centimeter (g/cc). The density of water is 1 g/cc since 1 cc has a mass of 1 g.

Specific gravity (SpG) is the ratio of the density of a substance (at a given temperature) to the density of water at the temperature of its maximum density (4°C).

Numerically, SpG is equal to the density in g/cc, but is expressed as a pure number without units. If the SpG of a substance is greater than 1 (the SpG of water), it will sink in water. The substance will float on water if its SpG is less than 1. This is important when considering mitigation and treatment methods.

Vapor Density--

The density of a gas or vapor can be compared to the density of the ambient atmosphere. If the density of a vapor or gas is greater than that of the ambient air, then it will tend to settle to the lowest point. If vapor density is close to air density or lower, the vapor will tend to disperse in the atmosphere. Vapor density is given in relative terms similar to specific gravity.

In settling, dense vapor creates two hazards. First, if the vapor displaces enough air to reduce the atmospheric concentration of oxygen below 16%, asphyxia may result. Second, if the vapor is toxic, then inhalation problems predominate even if the atmosphere is not oxygen deficient. If a substance is explosive and very dense, the explosive hazard may be close to the ground rather than at the breathing zone (normal sampling heights).

Vapor Pressure--

The pressure exerted by a vapor against the sides of a closed container is called vapor pressure. It is temperature dependent. As temperature increases, so does the vapor pressure. Thus, more liquid evaporates or vaporizes. The lower the boiling point of the liquid, the greater the vapor pressure it will exert at a given temperature. Values for vapor pressure are most often given as millimeters of mercury (mm H_g) at a specific temperature.

Boiling Point--

The boiling point is the temperature at which a liquid changes to a vapor - that is, it is the temperature where the pressure of the liquid equals atmospheric pressure. The opposite change in phases is the condensation point. Handbooks usually list temperatures as degrees Celsius (°C) or Fahrenheit (°F). A major consideration with toxic substances is how they enter the body. With high-boiling-point liquids, the most common entry is by body contact. With low-boiling-point liquids, the inhalation route is the most common and serious.

Melting Point--

The temperature at which a solid changes phase to a liquid is the melting point. This temperature is also the freezing point, since a liquid can change phase to a solid. The proper terminology depends on the direction of the phase change.

If a substance has been transported at a temperature that maintains a solid phase, then a change in temperature may cause the solid to melt. The particular substance may exhibit totally different properties, depending on phase. One phase could be inert while the other could be highly reactive. Thus, it is imperative to recognize the possibility of a substance changing phase due to changes in the ambient temperature.

Flash point

If the ambient temperature in relation to the material of concern is right, then it may give off enough vapor at its surface to allow ignition by an open flame or spark.

The minimum temperature at which a substance produces sufficient flammable vapors to ignite is its flash point. If the vapor does ignite, combustion can continue as long as the temperature remains at or above the flash point.

The relative flammability of a substance is based on its flash point. An accepted relation between the two is:

Highly flammable:	Flash point less than 100°F
Moderately flammable:	Flash point greater than 100°F but less than 200°F
Relatively inflammable:	Flash point greater than 200°F

SECTION 8

HAZARDOUS SUBSTANCE IDENTIFICATION SYSTEMS

INTRODUCTION

Hazardous materials are stored and transported in large quantities. Frequently, some stored or transported material is released, presenting a potential hazard to the public and environment. Such an incident can be managed more expeditiously when the hazardous material is specifically identified and characterized. Unfortunately, the contents of storage tanks or trucks may not be identified specifically or properly. Records or shipping papers may be inaccessible. Even with such information, an experienced person is needed to define the hazards and their seriousness.

Because of the immediate need for information concerning a hazardous material, two systems for hazard identification have been developed. Both help responders to deal with a hazardous material incident quickly and safely, and both were devised for persons untrained in chemistry.

The first is the National Fire Protection Association (NFPA) 704 M System, which is used mostly on storage tanks and smaller cotainers. The second system is used exclusively on containers and tanks transported in interstate commerce. The U.S. Department of Transportation (DOT) is responsible for this system. Its use, by way of placards and labels, is required under DOT regulations found in the Code of Federal Regulations 49 (49 CFR).

NEPA 704 M HAZARD IDENTIFICATION SYSTEM

Description

The NFPA is a standardized system which used numbers and colors on a sign to define the basic hazards of a specific material. The three, Health, Flammability, and Reactivity, are identified and rated on a scale of 0 to 4 depending on the degree of hazard presented (Figure 8.1).

The ratings for individual chemicals can be found in the NFPA "Guide to Hazardous Materials". Other references such as the U.S. Coast Guard manual, CHRIS Volume 2, and the National Safety Council's "Fundamentals of Industrial Hygiene" contain the NFPA ratings for specific chemicals. Such information can be useful not only in emergencies but also during long-term remedial activities when extensive evaluation is required.

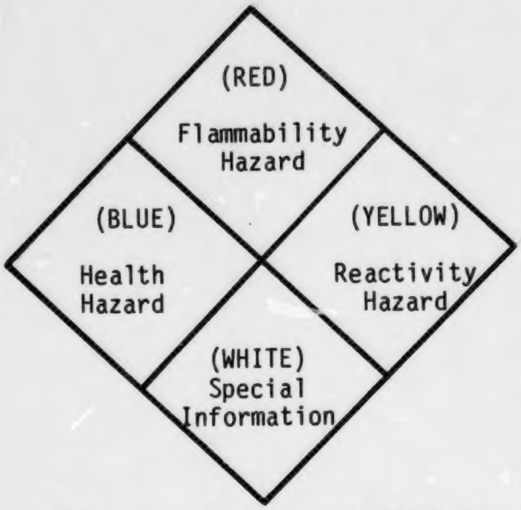


FIGURE 8-1. NFPA 704 M HAZARD IDENTIFICATION SYSTEM

Summary of Hazard Ranking System

Health Hazard (Blue)--

Rank Number	Description	Examples
4	Materials that on very short exposure could cause death or major residual injury even though prompt medical treatment was given.	Acrylonitrile Bromine Parathion
3	Materials that on short exposure could cause serious temporary or residual injury even though prompt medical treatment was given.	Aniline Sodium hydroxide Sulfuric acid
2	Materials that on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment was given.	Bromobenzene Pyridine Styrene
1	Materials that on exposure would cause irritation but only minor residual injury even if no treatment was given.	Acetone Methanol
0	Materials that on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.	

Flammability Hazard (Red)--

Rank Number	Description	Examples
4	Materials that (1) rapidly or completely vaporize at atmospheric pressure and normal ambient temperatures and burn readily or (2) are readily dispersed in air and burn readily.	1, 3-Butadiene Propane Ethylene oxide
3	Liquids and solids that can be ignitied under almost all ambient temperature conditions.	Phosphorus Acrylonitrile
2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	2-Butanone Kerosene
1	Materials that must be preheated before ignition can occur.	Sodium Red phosphorus
0	Materials that will not burn.	

Reactivity Hazard (Yellow)--

Rank Number	Description	Examples
4	Materials that in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.	Benzoyl peroxide Picric acid TNT
3	Materials that (1) in themselves are capable of detonation or explosive reaction but require a strong initiating source or (2) must be heated under confinement before initiation or (3) react explosively with water.	Diborane Ethylene oxide 2-Nitropropane
2	Materials that (1) in themselves are normally unstable and readily undergo violent chemical change but do not detonate or (2) may react violently with water or (3) may form potentially explosive mixtures with water.	Acetaldehyde Potassium

Rank Number	Description	Examples
1	Materials that in themselves are normally stable but which can (1) become unstable at elevated temperatures or (2) react with water with some release of energy but not violently.	Ethyl ether Sulfuric acid
0	Materials that in themselves are normally stable, even when exposed to fire, and that do not react with water.	

Special Information (White)--

The white block denotes special information about the chemical. For example, it may indicate that the material is radioactive by displaying the standard radioactive symbol, or unusually water-reactive by displaying a large W with a slash through it (W̸). For a more complete discussion of these various hazards, consult the NFPA Standard 704 M.

DOT HAZARD INFORMATION SYSTEM

The DOT's Hazardous Materials Transportation Administration regulates over 1,400 hazardous materials. The regulations require labels on small containers and placards on tanks and trailers. These placards and labels indicate the nature of the hazard presented by the cargo. The classification used for the placards and labels is based on the United Nations Hazard Classes (Table 8.1). The UN hazard class number is found in the bottom corner of a DOT placard or label.

The various hazards are defined in Table 8.2.

TABLE 8.1. UN HAZARD CLASS SYSTEM

United Nations Hazard Class Number	Description
1	Class A, B, and C Explosives
2	Nonflammable and flammable compressed gases
3	Flammable liquids
4	Flammable solids, spontaneously combustible substances, and water-reactive substances
5	Oxidizing materials, including organic peroxides
6	Class A and B poisons, irritants, and etiologic (disease-causing) materials
7	Radioactive materials
8	Corrosive materials (acids, alkaline liquids, and certain corrosive liquids and solids)
9	Miscellaneous hazardous materials not covered by any of the other classes

To facilitate handling a hazardous material incident, some placards are being altered to accept a 4-digit identification number (Figure 8.2). This number comes from the Hazardous Material Table in the DOT regulations, 49 CFR 172.101. This ID number also must be written on the shipping papers or manifest. In the event of an incident, the ID number on the placard will be much easier to obtain than the shipping papers. Once the number is obtained, the DOT's "Emergency Response Guide Book" can be consulted. This book describes the proper methods and precautions for responding to release of each hazardous material with an ID number. The DOT system goes one step further in aiding response personnel than the NFPA system. However, using both systems when responding to hazardous material incidents will help to identify and characterize the materials involved properly.

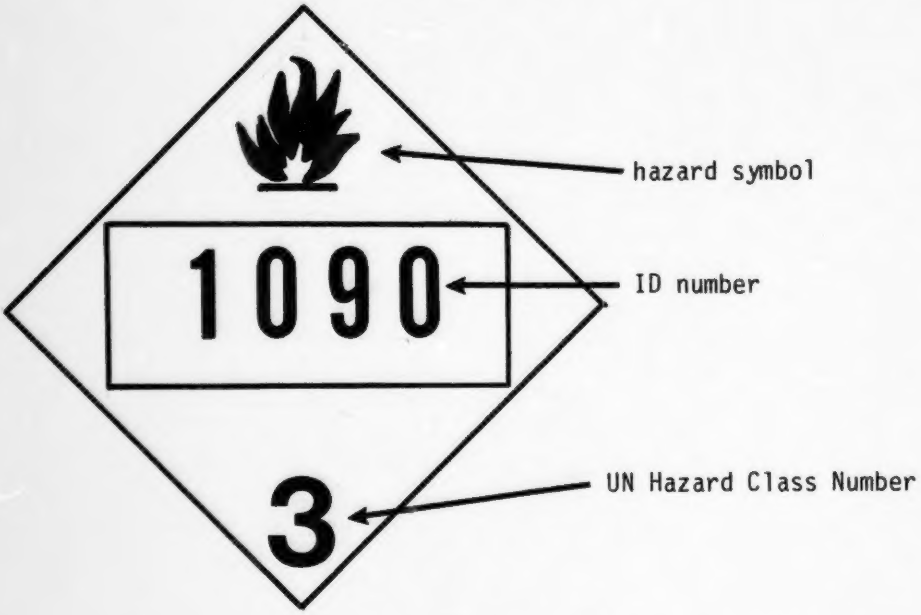
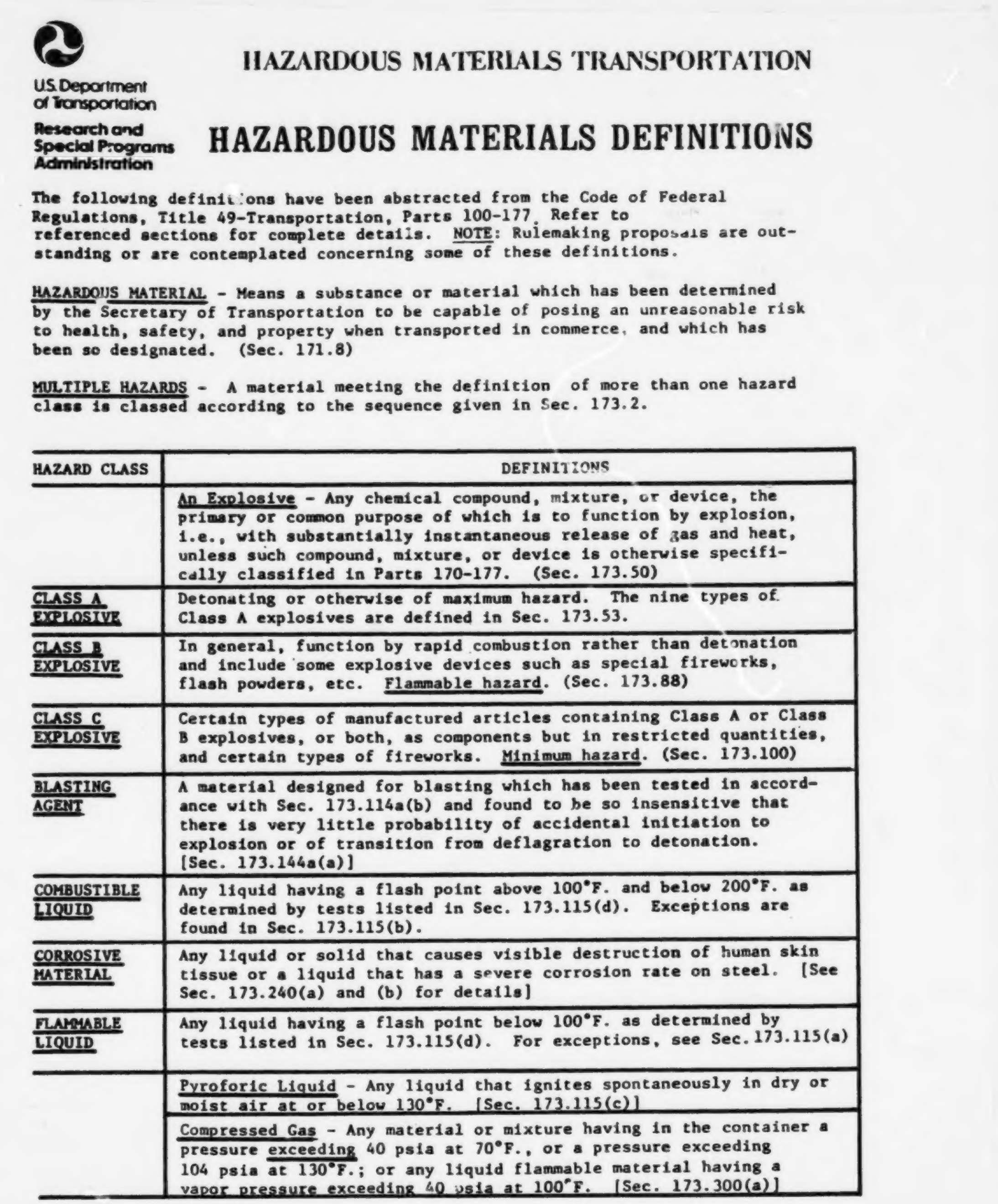


Figure 8.2. MODIFICATION OF DOT HAZARD IDENTIFICATION SYSTEM

TABLE 8.2. Hazardous Materials Definitions



U.S. Department of Transportation
Research and Special Programs Administration

HAZARDOUS MATERIALS TRANSPORTATION

HAZARDOUS MATERIALS DEFINITIONS

The following definitions have been abstracted from the Code of Federal Regulations, Title 49-Transportation, Parts 100-177. Refer to referenced sections for complete details. NOTE: Rulemaking proposals are outstanding or are contemplated concerning some of these definitions.

HAZARDOUS MATERIAL - Means a substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. (Sec. 171.8)

MULTIPLE HAZARDS - A material meeting the definition of more than one hazard class is classed according to the sequence given in Sec. 173.2.

HAZARD CLASS	DEFINITIONS
	An Explosive - Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion, i.e., with substantially instantaneous release of gas and heat, unless such compound, mixture, or device is otherwise specifically classified in Parts 170-177. (Sec. 173.50)
CLASS A EXPLOSIVE	Detonating or otherwise of maximum hazard. The nine types of Class A explosives are defined in Sec. 173.53.
CLASS B EXPLOSIVE	In general, function by rapid combustion rather than detonation and include some explosive devices such as special fireworks, flash powders, etc. Flammable hazard. (Sec. 173.88)
CLASS C EXPLOSIVE	Certain types of manufactured articles containing Class A or Class B explosives, or both, as components but in restricted quantities, and certain types of fireworks. Minimum hazard. (Sec. 173.100)
BLASTING AGENT	A material designed for blasting which has been tested in accordance with Sec. 173.114a(b) and found to be so insensitive that there is very little probability of accidental initiation to explosion or of transition from deflagration to detonation. [Sec. 173.144a(a)]
COMBUSTIBLE LIQUID	Any liquid having a flash point above 100°F. and below 200°F. as determined by tests listed in Sec. 173.115(d). Exceptions are found in Sec. 173.115(b).
CORROSIVE MATERIAL	Any liquid or solid that causes visible destruction of human skin tissue or a liquid that has a severe corrosion rate on steel. [See Sec. 173.240(a) and (b) for details]
FLAMMABLE LIQUID	Any liquid having a flash point below 100°F. as determined by tests listed in Sec. 173.115(d). For exceptions, see Sec. 173.115(a)
	Pyroforic Liquid - Any liquid that ignites spontaneously in dry or moist air at or below 130°F. [Sec. 173.115(c)]
	Compressed Gas - Any material or mixture having in the container a pressure exceeding 40 psia at 70°F., or a pressure exceeding 104 psia at 130°F.; or any liquid flammable material having a vapor pressure exceeding 40 psia at 100°F. [Sec. 173.300(a)]

TABLE 8.2 (Continued)

HAZARD CLASS	DEFINITIONS
FLAMMABLE GAS	Any compressed gas meeting the requirements for lower flammability limit, flammability limit range, flame projection, or flame propagation criteria as specified in Sec. 173.300(b)
NONFLAMMABLE GAS	Any compressed gas other than a flammable compressed gas.
FLAMMABLE SOLID	Any solid material, other than an explosive, which is liable to cause fires through friction, retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious transportation hazard. (Sec. 173.150)
ORGANIC PEROXIDE	An organic compound containing the bivalent -O-O structure and which may be considered a derivative of hydrogen peroxide where one or more of the hydrogen atoms have been replaced by organic radicals must be classed as an organic peroxide unless--[See Sec. 173.151(a) for details]
OXIDIZER	A substance such as chlorate, permanganate, inorganic peroxide, or a nitrate, that yields oxygen readily to stimulate the combustion of organic matter. (See Sec. 173.151)
POISON A	Extremely Dangerous Poisons - Poisonous gases or liquids of such nature that a very small amount of the gas, or vapor of the liquid, mixed with air is dangerous to life. (Sec. 173.326)
POISON B	Less Dangerous Poisons - Substances, liquids, or solids (including pastes and semi-solids), other than Class A or Irritating materials, which are known to be so toxic to man as to afford a hazard to health during transportation; or which, in the absence of adequate data on human toxicity, are presumed to be toxic to man. (Sec. 173.343)
IRRITATING MATERIAL	A liquid or solid substance which upon contact with fire or when exposed to air gives off dangerous or intensely irritating fumes, but not including any poisonous material, Class A. (Sec. 173.381)
ETIOLOGIC AGENT	An "etiologic agent" means a viable micro-organism, or its toxin which causes or may cause human disease. (Sec. 173.386)
RADIOACTIVE MATERIAL	Any material, or combination of materials, that spontaneously emits ionizing radiation, and having a specific activity greater than 0.002 microcuries per gram. (Sec. 173.389) NOTE: See Sec. 173.389(a) through (1) for details.
ORM-OTHER REGULATED MATERIALS	(1) Any material that may pose an unreasonable risk to health and safety or property when transported in commerce; and (2) Does not meet any of the definitions of the other hazard classes specified; or (3) Has been reclassed an ORM (specifically or permissively) according to this subchapter [Sec. 173.500(a)] NOTE: A material with a flashpoint of 100°F. to 200°F. may not be classed as an ORM if it is a hazardous waste or is offered in a packaging having a rated capacity of more than 110 gallons.
ORM-A	A material which has an anesthetic, irritating, noxious, toxic, or other similar property and which can cause extreme annoyance or discomfort to passengers and crew in the event of leakage during transportation. [Sec. 173.500(b)(1)]

TABLE 8.2 (Continued)

HAZARD CLASS	DEFINITIONS
ORM-B	A material (including a solid when wet with water) capable of causing significant damage to a transport vehicle or vessel from leakage during transportation. Materials meeting one or both of the following criteria are ORM-B materials: (i) A liquid substance that has a corrosion rate exceeding 0.250 inch per year (IPY) on aluminum (nonclad 7075-T6) at a test temperature of 130°F. An acceptable test is described in NACE Standard TM-01-69, and (ii) Specifically designated by name in Sec. 172.101. [Sec. 173.500 (b)(2)]
ORM-C	A material which has other inherent characteristics not described as an ORM-A or ORM-B but which makes it unsuitable for shipment, unless properly identified and prepared for transportation. Each ORM-C material is specifically named in Sec. 172.101. [Sec. 173.500(b)(3)]
ORM-D	A material such as a consumer commodity which, though otherwise subject to the regulations of this subchapter, presents a limited hazard during transportation due to its form, quantity and packaging. They must be materials for which exceptions are provided in Sec. 172.101. A shipping description applicable to each ORM-D material or category of ORM-D materials is found in Sec. 172.101. [Sec. 173.500(b)(4)]
ORM-E	A material that is not included in any other hazard class, but is subject to the requirements of this subchapter. Materials in this class include (i) Hazardous wastes and (ii) Hazardous substances as defined in Sec. 171.8. [Sec. 173.500(b)(5)]
THE FOLLOWING ARE OFFERED TO EXPLAIN ADDITIONAL TERMS USED IN PREPARATION OF HAZARDOUS MATERIALS FOR SHIPMENT. (Sec. 171.8)	
CONSUMER COMMODITY (See ORM-D)	Means a material that is packaged or distributed in a form intended and suitable for sale through retail sales agencies or instrumentalities for consumption by individuals for purposes of personal care or household use. This term also includes drugs and medicines. (Sec. 171.8)
FLASH POINT	Means the minimum terperature at which a substance gives off flammable vapors which in contact with a spark or flame will ignite. For liquids, see Sec. 173.115; for solids, see Sec. 173.150.
FORBIDDEN	Means that the material is prohibited from being offered or accepted for transportation. NOTE: This prohibition does not apply if these materials are diluted, stabilized, or incorporated in devices and they are classed in accordance with the definitions of hazardous materials. [Sec. 172.101(d)(1)]
HAZARDOUS SUBSTANCES	For transportation purposes, means a material, and its mixtures or solutions, that is identified by the letter "E" in Column 2 of the Hazardous Materials Table to Sec. 172.101 when offered for transportation in one package, or in one transport vehicle if not packaged, and when the quantity of the material therein equals or exceeds the reportable quantity (RQ). For details, refer to Sec. 171.8 and Sec. 172.101. Hazardous Materials table.

TABLE 8.2 (Continued)

HAZARDOUS WASTES	For transportation purposes, means any material that is subject to the hazardous waste manifest requirements of the Environmental Protection Agency in CFR, Title 40, Part 123, Chapter F. (Sec. 171.8) For details on the Hazardous Waste and Consolidated Permit Regulations refer to CFR, Title 40, Parts 260-267 and Parts 122-125. Questions regarding these regulations, call Toll Free: (800) 424-9346 or (202) 554-1404
LIMITED QUANTITY	Means the maximum amount of a hazardous material; as specified in those sections applicable to the particular hazard class, for which there are specific exceptions from the requirements of this subchapter. See Sec. 173.118, 173.118(a), 173.153; 173.244, 173.306, 173.345 and 173.364.
REPORTABLE QUANTITY	For transportation purposes, means the quantity of hazardous substance and/or hazardous waste specified in the Hazardous Material Table, Column 2 and identified by the letter "E" in Column 1. (Sec. 171.8)
SPONTANEOUSLY COMBUSTIBLE MATERIAL (SOLID)	Means a solid substance (including sludges and pastes) which may undergo spontaneous heating or self-ignition under conditions normally incident to transportation or which may, upon contact with the atmosphere, undergo an increase in temperature and ignite. (Sec. 171.8)
WATER REACTIVE MATERIAL (SOLID)	Means any solid substance (including sludges and pastes) which, by interaction with water, is likely to become spontaneously flammable or to give off flammable or toxic gases in dangerous quantities. (Sec. 171.8)

NOTE: This handout is designed as a training aid for all interested parties who may become involved with hazardous materials. It does not relieve persons from complying with the Department of Transportation Hazardous Materials Regulations. Final author for use of these hazard classes and definitions is found in CFR, Title 49, Parts 100-177.

Information Services Division, DMT-11
Office of Operations and Enforcement
Materials Transportation Bureau
Research and Special Programs Administration
Department of Transportation
Washington, D.C. 20590

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REVISED FEBRUARY 1981

SECTION 9

USE OF THE HAZARDOUS SUBSTANCE DATA SHEET

INTRODUCTION

A hazardous substance data sheet is an effective means of presenting data on a particular compound and the related incident. It is much easier for response personnel to have the necessary information in one place than continually to consult different sources which may or may not have the desired data. Condensing the information on physical, chemical, and toxicological properties of the compound and incident onto two pages also speeds briefing of any personnel arriving on site when time is important. As many sources as possible should be used to fill out the sheets as some information on the same property may vary from one reference to another.

FILLING OUT THE HAZARDOUS SUBSTANCE DATA SHEET

Under "Name of Substance," list both the common name and the name approved by the International Union for Pure and Applied Chemistry (IUPAC). Both should be entered, since it may be necessary to look up information under different names. If a compound uses more than one common name, list all synonyms. Write in the formula after the chemical name, because some references index chemicals by their formulas.

Part I lists the physical/chemical properties of the compound. In the far right column labeled "Source," enter the reference from which the information was obtained. If the information is found later to be incorrect or conflicting, it may be corrected. It also makes it easier to refer back to a particular source if additional information is needed. The properties included in the data sheet are:

> Normal Physical State: Check the appropriate space for the physical state of the chemical at normal ambient temperatures (20°C-24°C).
>
> Molecular Weight: Usually expressed in grams per gram-mole. This information is essential because neutralization or any other chemical treatment would require the number of moles of chemical present.
>
> Density and Specific Gravity: Only one is required. Density is usually expressed in grams per milliliter. Specific gravity is dimensionless. Indicate the temperature at which specific gravity is measured and circle the appropriate letter corresponding to degrees Fahrenheit(°F) or Celsius(°C).

Solubility: Water: Usually expressed in parts per million or milligrams per liter, which are equivalent (that is, 1 ppm = 1 mg/L). Solubility is temperature dependent.

Solubility: Enter any other material for which solubility data are needed. For instance, recovering a spilled material by solvent extraction may require solubility data for any one of a number of organic compounds.

Boiling Point: Expressed in degrees Fahrenheit or Celsius. It is the temperature at which the vapor pressure of the compound equals atmospheric pressure (760 mm mercury at sea level). The boiling point is raised if any impurities are present.

Melting Point: Same as freezing point. Melting point is lowered if any impurities are present.

Vapor Pressure: Usually expressed in millimeters of mercury or atmospheres at a given temperature. Strongly temperature dependent.

Vapor Density: Dimensionless quantity. Expressed relative to air.

Flash Point: Expresed in degrees Fahrenheit or Celsius. Indicate whether the figure is based on an open cup or closed cup test.

Other: Enter any miscellaneous data, for example biochemical oxygen demand, autoignition temperature, or odor threshold concentrations.

Part II is a compilation of five types of hazardous charcteristics. In the far right column labeled "Source", enter the reference from which the information was obtained.

Section A list toxicological hazards:

Inhalation: Under "Concentrations," enter the current TLV (Threshold Limit Value) concentration. This is important for selecting levels of protection for workers who will be in the area.

Ingestion: Enter the toxicity level in milligrams per kilogram (mg/kg) of the body weight.

Skin/Eye Absorption - Contact: Determine from the references whether these hazards exist.

Carcinogenic, Teratogenic, Mutagenic: It is difficult to obtain concentration data on these hazards, since very little is known about the mechanisms which cause these effects.

Aquatic: Usually expressed in parts per million (ppm) for a particular species.

Other: Enter an IDLH (Immediately Dangerous to Life or Health) concentration, or any other pertinent miscellaneous information.

Section B contains fire hazard data:

Combustibility: Applies to any compound which can be oxidized in air. Almost every organic compound is combustible.

Toxic By-products: If the compound is combustible, enter yes, because all combustion processes yield some carbon monoxide. List the particular toxic by-products in the spaces below.

Flammability/Explosiveness Limits: Expressed as a percentage by volume in air. Usually flammable limits and explosive limits are synonymous.

Section C contains reactivity data:

Reactivity Hazard: If the material is reactive, indicate the substances which are incompatible with the material.

Section D contains corrosivity data:

pH: Some references give the pH of an aqueous solution at a given concentration. For instance, the pH of 0.5% solution of sodium hydroxide is 13. There is also space for listing the types of materials known to be corroded by the compound in question.

Neutralizing Agent: Some references list neutralizing materials which may help at an incident by bringing the pH of the affected area to neutral (pH of 7).

Section E contains radioactivity data:

Background: List a background level. Background is usually on the order of 0.01 milliroentgens per hour (mR/hour). See Part 2, "Field Monitoring".

Alpha, Beta, Gamma: Exposure rates on some elements may be found in the "Radiological Health Handbook," published by the U.S. Department of Health and Human Services.

Parts III, IV, and V of the sheet describe the specific incident and recommend safety measures. Sometimes, parts of the following sections will be left blank, simply because of a lack of accurate information. Enter available incident information as promptly as possible, however, so that mitigation measures can start.

Part III describes the incident:

Quantity Involved: Usually express in gallons, barrels, or liters for a liquid, and pounds or kilograms for a solid.

Release Information: Indicate if the container(s) is (are) still leaking, and if possible, the rate of discharge.

Monitoring/Sampling Recommended: Indicate what type(s) of monitoring should be initiated to completely characterize an incident and if on-site samples are necessary. See sections on Sampling and Field Monitoring.

Part IV, Recommended Protection, covers:

Public: Based on the data obtained in the first three parts and the proximity of the incident to populated areas, make an initial public hazard evaluation. The OHMTADS reference segment Number 111, "Degree of Hazard to Public Health," is helpful in recommending action to protect public health.

Environment: Depending on the type of release and potential pathways of dispersion, propose potential activities such as booming, skimming, or chemical/physical treatment. OHMTADS segments 113, "Action Levels," and 114, "In Situ Amelioration," can help determine initial response activities.

Worker: Decide on levels of protection for response personnel, once again based on the physical, chemical, and toxicological properties of the materials in question. OHMTADS segment 108, "Personal Safety Precautions," aids in this decision. See also "Standard Operating Safety Guides," Part 5.

Part V, Recommended Site Control, covers:

If enough information is available, establish three work zones (See Standard Operating Procedures, Part 6):

- Exclusion Zone (contaminated)
- Contamination Reduction Zone
- Support Zone (non-contaminated)

Hotline: Establish site boundary.
Any person who crosses the Hotline (the outer boundary of the Exclusion Zone) must be in the proper level of protection predesignated by the site safety officer.

Decontamination Line: Based upon the toxicity of the compound(s) involved, establish a decontamination system in the Contamination Reduction zone. "See Standard Operating Safety Guides," Part 7.

Command Post Location: Locate the command post. This decision is usually constrained by wind direction, accessibility, and logistical considerations. It should also be a safe distance from the Hotline.

EXAMPLE OF DOCUMENTATION NEEDED TO COMPLETE A HAZARDOUS SUBSTANCE DATA SHEET (PARTS I AND II)

Benzene has been chose as an example. For purposes of illustration, seven sources of information were utilized:

- "Condensed Chemical Dictionary" by Gessner G. Hawley
- "The Merck Index"
- "Dangerous Properties of Industrial Materials" by N. Irving Sax
- "NIOSH/OSHA Pocket Guide to Chemical Hazards"
- "Documentation of the Threshold Limit Values (TLV)"
- CHRIS, Volume 2
- OHMTADS

V. HAZARDOUS SUBSTANCE DATA SHEET

SUBSTANCE:

COMMON: ____________________ CHEMICAL: ____________________

I. PHYSICAL/CHEMICAL PROPERTIES

			SOURCE
Normal Physical State:	____ Gas ____ Liquid ____ Solid		____
Molecular Weight	____		____
Density	____	g/ml	____
Specific gravity	____ @ ____	°F/°C	____
Solubility: Water	____ @ ____	°F/°C	____
Solubility: ____	____	°F/°C	____
Boiling Point	____	°F/°C	____
Melting Point	____	°F/°C	____
Vapor Pressure	____ mmHg	°F/°C	____
Vapor Density	____ @ ____	°F/°C	____
Flash Point	____	°F/°C	____
Other: ____	____		
____	____		

II. HAZARDOUS CHARACTERISITICS

A. TOXICOLOGICAL HAZARD

	HAZARD		CONCENTRATIONS	SOURCE
Inhalation	Yes	No	____	____
Ingestion	Yes	No	____	____
Skin/Eye Absorption	Yes	No	____	____
Skin/Eye Contact	Yes	No	____	____
Carcinogenic	Yes	No	____	____
Teratogenic	Yes	No	____	____
Mutagenic	Yes	No	____	____
Aquatic	Yes	No	____	____
Other: ____	Yes	No	____	____

B. FIRE HAZARD

			CONCENTRATIONS	SOURCE
Combustibility	Yes	No	____	____
Toxic Byproducts:	Yes	No	____	____
____				
____				
Flammability	Yes	No		
LFL			____	____
UFL			____	____
Explosiveness	Yes	No		
LEL			____	____
UEL			____	____

C. REACTIVITY HAZARD

			CONCENTRATIONS	SOURCE
REACTIVITY HAZARD	Yes	No		
____			____	____
____			____	____

	HAZARD		CONCENTRATIONS	SOURCE
D. CORROSIVITY HAZARD	Yes	No		____________
pH__________				
Neutralizing agent:				
____________			____________	____________
____________			____________	____________

			EXPOSURE RATE	SOURCE
E. RADIOACTIVE HAZARD	Yes	No	EXPOSURE RATE	SOURCE
Background			____________	____________
Alpha Particles			____________	____________
Beta Particles			____________	____________
Gamma Radiation			____________	____________

III. DESCRIPTION OF INCIDENT:

Quantity Involved ____________

Release Information ____________

Monitoring/Sampling Recommended ____________

IV. RECOMMENDED PROTECTION:

Public ____________

Environment ____________

Worker ____________

V. RECOMMENDED SITE CONTROL:

Hotline ____________

Decontamination Line ____________

Command Post Location ____________

IV. EXAMPLE -- COMPLETED

HAZARDOUS SUBSTANCE DATA SHEET

SUBSTANCE: BENZENE

COMMON: BENZENE (BENZOL, CYCLOHEXATRIENE) CHEMICAL: BENZENE, C_6H_6

I. PHYSICAL/CHEMICAL PROPERTIES

Normal Physical State: ___ Gas ✓ Liquid ___ Solid

			SOURCE
Normal Physical State	Liquid		CHRIS II
Molecular Weight	78.11		CHRIS II
Density		gm/ml	
Specific gravity	0.879 @ 20	°F/[✓ °C]	CHRIS II
Solubility: Water	820 ppm @ 25	°F/[✓ °C]	OHMTADS
Solubility:		°F/°C	
Boiling Point	176	[✓ °F]/°C	CHRIS II
Melting Point	42	[✓ °F]/°C	CHRIS II
Vapor Pressure	100 mmHg 26.1	°F/[✓ °C]	SAX
Vapor Density	2.77 @ 20	°F/[✓ °C]	OHMTADS
Flash Point (CC)	12	[✓ °F]/°C	SAX
Other:			

II. HAZARDOUS CHARACTERISITICS

A. TOXICOLOGICAL HAZARD

TOXICOLOGICAL HAZARD	HAZARD	CONCENTRATIONS	SOURCE
Inhalation	[✓ Yes] No	25 ppm TLV	CHRIS II
Ingestion	[✓ Yes] No	0.174 mg/Kg (HUMAN)	OHMTADS
Skin/Eye Absorption	[✓ Yes] No		SAX
Skin/Eye Contact	[✓ Yes] No		SAX
Carcinogenic	[✓ Yes] No		SAX
Teratogenic	Yes No		
Mutagenic	Yes No		
Aquatic	Yes No		
Other: IDLH level	[✓ Yes] No	2000 ppm	NIOSH/OSHA GUIDE

B. FIRE HAZARD

FIRE HAZARD	HAZARD	CONCENTRATIONS	SOURCE
Combustibility	[✓ Yes] No		
Toxic Byproducts:	[✓ Yes] No		
Flammability	[✓ Yes] No		
LFL		1.3%	CHRIS II
UFL		7.9%	
Explosibility	[✓ Yes] No		
LEL		1.3%	CHRIS II
UEL		7.9%	

C. REACTIVITY HAZARD

REACTIVITY HAZARD	HAZARD	CONCENTRATIONS	SOURCE
w/ OXIDIZING MAT'LS O_2, O_3 ALSO Cl_2, CrO_3, PERCHLORATES, PEROXIDES H_2SO_4	[✓ Yes] No		SAX, OHMTADS

	HAZARD	CONCENTRATIONS	SOURCE
D. CORROSIVITY	Yes [✓ No]		OHMTADS
pH			
Neutralizing agent:			

		EXPOSURE RATE	SOURCE
E. RADIOACTIVE HAZARD	Yes [✓ No]		
Background			CHRIS II
Alpha Particles			
Beta Particles			
Gamma Radiation			

III. INCIDENT RELATED:

Quantity Involved

Release Information

Monitoring/Sampling Recommended

V. RECOMMENDED PROTECTION:

Public

Environment

Worker

V. RECOMMENDED SITE CONTROL:

Hotline

Decontamination Line

Command Post Location

SECTION 10

DIVING PHYSIOLOGY

Roughly 80 percent of the Earth's air is the inert gas nitrogen. This inert gas is absorbed by body tissues when air is breathed under pressure. The same also is true when another inert gas, such as helium, is substituted for nitrogen on deeper dives. Each body tissue absorbs this gas at its own characteristic rate. Upon ascent, these tissues give up their absorbed gas at a rate that can be determined experimentally. The actual physiological processes involved are complicated and not yet completely understood; however, the body's reaction to this off-gassing can be understood without this knowledge.

If decompression is too rapid, small bubbles of inert gas will form in the tissues, causing a condition called Decompression Sickness (DCS) or the Bends. The diver experiences excruciating pain in his joints, and the condition can lead to serious complications if not immediately and properly treated. This treatment usually involves placing the patient under pressure in a recompression chamber as a major part of the overall remedy.

A volume of gas descending in water halves its volume approximately every 33 feet. The inverse is true upon ascent. If the volume of air in question is in a diver's lungs, and if he does not expel the air as he ascends, the expanding air will force its way through the walls of the alveoli, causing bubbles to form in the blood vessels. This condition is known as a gas embolism and can occur in as shallow as four feet of water. Should one of these bubbles block the flow of blood, and thus oxygen, to a vital organ (especially the brain), serious and immediate consequences would result. If the situation is not immediately and properly treated, the victim probably will die. As the treatment for DCS, treatment for embolism also involves recompression.

For the diver, a controlled ascent is extremely important. As important, is allowing sufficient time for the dissolved gasses to come out of solution without forming the dangerous bubbles. The U.S. Navy Decompression Tables (U.S. Department of the Navy, 1973) were designed to assist the diver in this task and can be found in most diving references.

There are many other aspects of diving physiology, however, that are not pertinent to the subject of this manual. DCS and gas embolism are risks associated with every dive, risks easily exacerbated by unfamiliar equipment, or equipment that fails to function correctly.

SECTION 11

DIVING MODES AND EQUIPMENT

Diving has its roots in antiquity, but most significant developments have occurred during the last 400 years. With the invention of the two-stage demand regulator in 1943, diving became not only a work tool, but also a sport currently practiced by millions of enthusiasts around the world.

There are two basic diving modes. In *one atmosphere diving* the diver is encased in a rigid container or suit which contains air at the surface pressure of 14.7 pounds per square inch (psi). Some development was done on suits like this in the 1930's. Recently, much work has been done with the titanium *JIM Suit*, shown in Fig. 11.1, which is capable of allowing a diver to do functional work in a one atmosphere environment at depths exceeding 1,000 feet. The MANTIS, as shown in Figure 11.2, is a one person submersible vehicle which also operates at one atmosphere.

In *ambient diving* the diver is subjected to the ambient pressure of the water at the depth to which he is diving. Ambient diving consists of two major subgroupings, *surface supplied diving* and *self-contained diving* using some form of *Self-contained Underwater Breathing Apparatus (SCUBA)*. Surface supplied diving is that mode generally used by commercial diving activities. SCUBA diving, while primarily a sporting activity in terms of numbers of participants, is widely used in the scientific community for data collection and research support, and to some extent in the military as well.

Surface supplied diving. Surface supplied diving is the direct descendant of the Siebe diving dress discussed in the foregoing section. There are three modern applications. Modern hard-hat rigs are most similar in appearance to the original Siebe unit. Basically, they consist of some sort of rigid helmet (made of anything from brass to fiberglass) attached to some sort of waterproof suit. Fig. 11.3 shows both the new Navy MK-12 deep diving system and the original MK5 hard-hat rig used for decades. The suit is protected by appropriate one-way valving and is weighted to maintain *neutral buoyancy* when submerged. Air and communications are brought to the diver through an *umbilical* which also contains a strength member. When diving in a hard-hat rig, the diver can be considered isolated from his environment except for the effects of ambient pressure. A thorough description of specific equipment and procedures associated with surface supplied diving can be found in Sections 14, 15, and 22.

Diving from a *Personnel Transfer Capsule (PTC)* can be thought of as second order surface-supplied diving. Divers enter a *recompression chamber* at the surface. This chamber is large enough for them to live inside for

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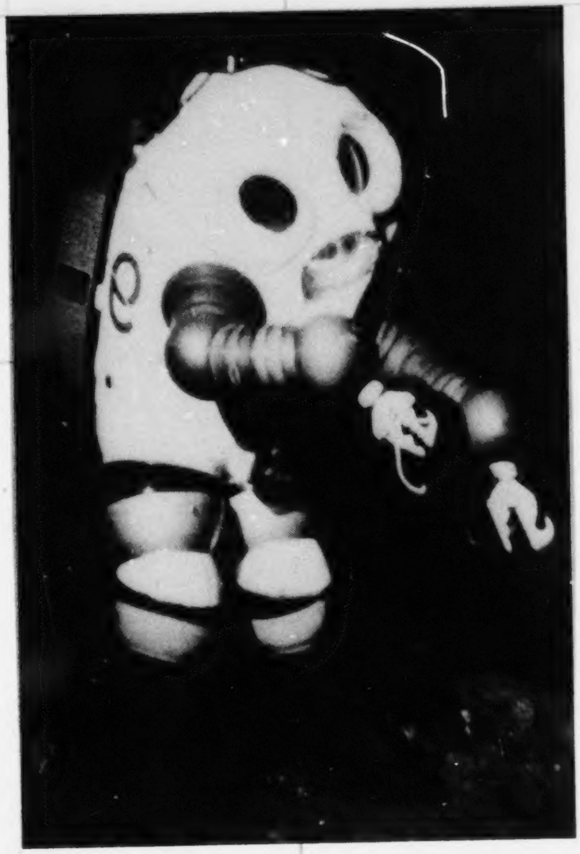

Figure 11.1 One Atmosphere JIM Suit

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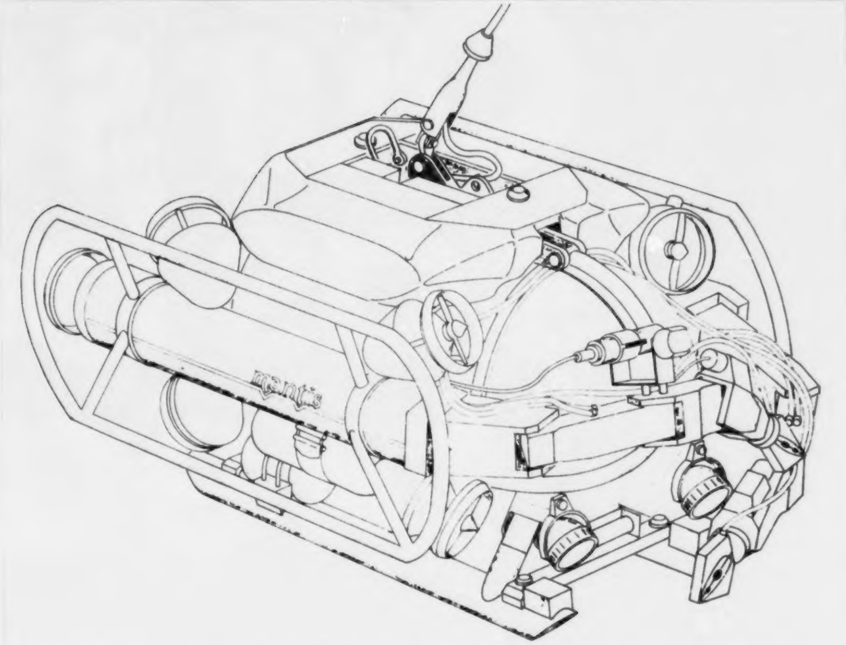

Line drawing of the Mantis submersible

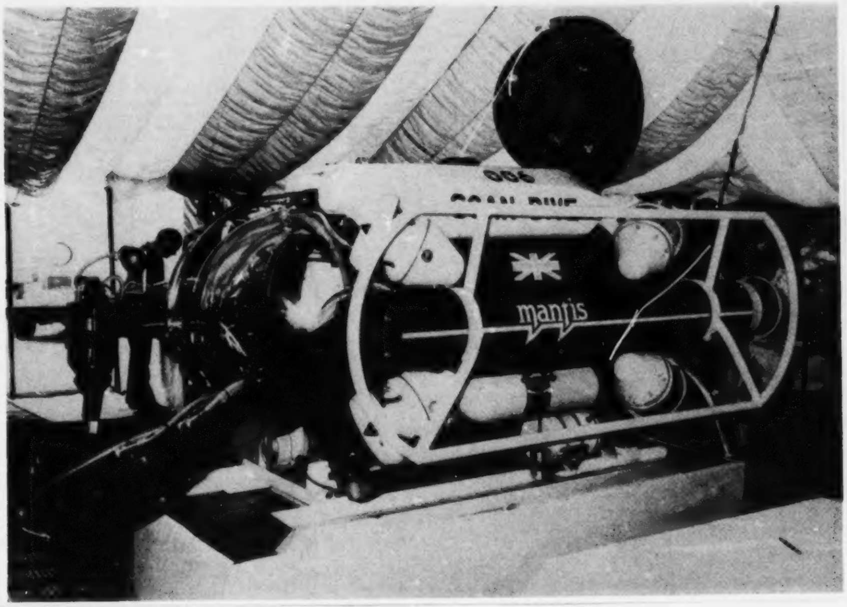

Figure 11.2 - MANTIS One-Man Submersible Vehicle

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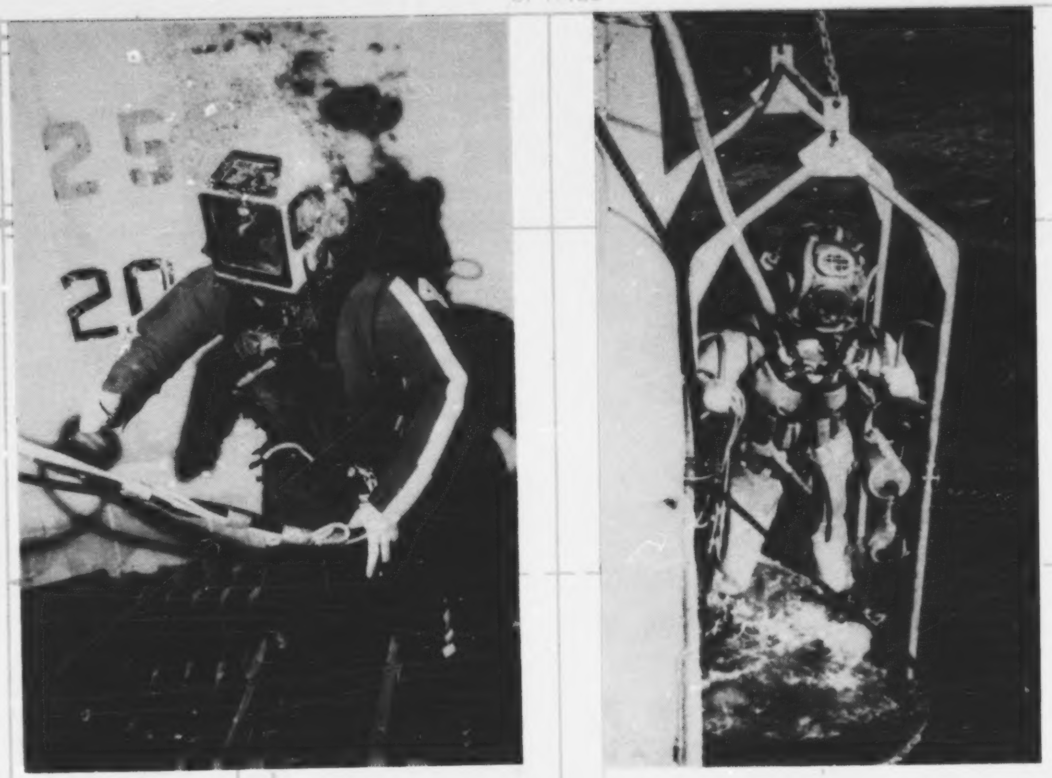

New Navy MK-12 Rig

Former Navy MK-5 Rig

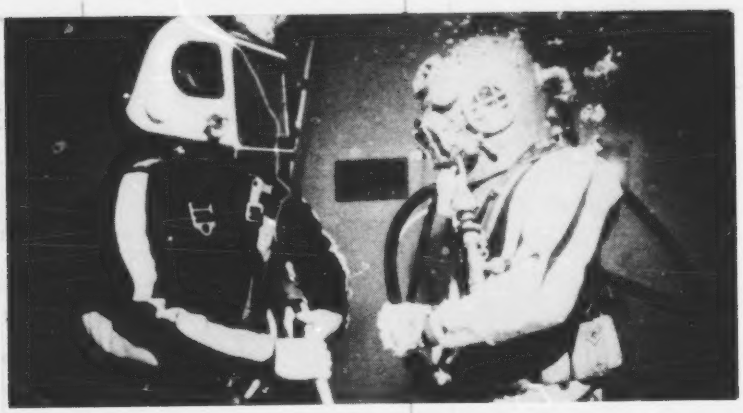

Figure 11.3 Current Navy MK-12 (Left) and Former MK-5 (Right) Deep Water Diving System.

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several days. The whole chamber is pressurized to the working depth of the dive. After about twelve hours the divers are saturated. When it is time to dive, they don their equipment and enter the PTC which is mated to the recompression chamber in some pressure-tight fashion. The PTC is sealed and lowered to diving depth. Usually a PTC is fed air, power, and communications through an umbilical from the surface. Occasionally it is self-sufficient for some period of time, except for the cable which suspends it at depth. Upon reaching depth, the divers open the PTC which remains dry because internal gas pressure balances outside water pressure. The divers wear band masks supplied through umbilicals from the PTC in the performance of their work outside the PTC.

Self-contained diving. Self-contained diving has two major subdivisions. Closed-circuit diving is the direct descendant of the work done in the late 1800's by Fleuss, Siebe, and Gorman. Open-circuit diving has changed very little since the invention of the open-circuit demand regulator by Cousteau and Gagnan in 1943. Equipment has kept pace with technology, but changes have been mere refinements of the original which still is acceptable for use under most circumstances today.

Closed circuit diving uses the principle that metabolically-produced carbon dioxide can be removed from the breathing gas mixture with pure oxygen and so eliminate the problem of maintaining the delicate balance between oxygen and the inert gas being used. When pure oxygen is being used, the diver normally is limited to a depth of 25 feet because of physiological complications that arise when oxygen is breathed at higher partial pressures. A tightly fitting mask must be worn to prevent the escape of gases around the rebreather mask. The unit has a bag into and from which the diver breathes. Exhaled gasses pass over a chemical (such as barium hydroxide) that absorbs carbon dioxide, and in the case of the more sophisticated units, the gas is monitored continuously to ensure that there is always sufficient, but not too much, oxygen present in the gas.

Rebreather units leave no telltale trail of bubbles, so they are ideally suited for clandestine military diving. When, for operational reasons, a diver on a deep dive cannot be anchored to an umbilical, he can dive for a longer period of time using a rebreather instead of open-circuit because his tank can be filled with pure oxygen instead of a very small percentage of oxygen mixed with a large amount of useless inert gas.

Since the rebreather is a self-contained unit, exhausting no gases, it may be suited for a polluted water diving dress which fully encapsulates not only the diver but the breathing apparatus as well. Further investigation is required in this area of equipment modification. Figure 11.4 illustrates an example of a closed-circuit diving system.

Open-circuit diving, commonly called SCUBA diving, and shown in Fig. 11.5, is the predominant form of noncommercial diving in the world today. It normally consists of one to three tanks of compressed air carried on the diver's back, feeding a regulator which reduces the tank pressure to some fixed pressure above ambient (usually between 120 and 140 psi). This first stage regulator feeds a second stage regulator which is attached to a mouthpiece through which the diver breathes. This second

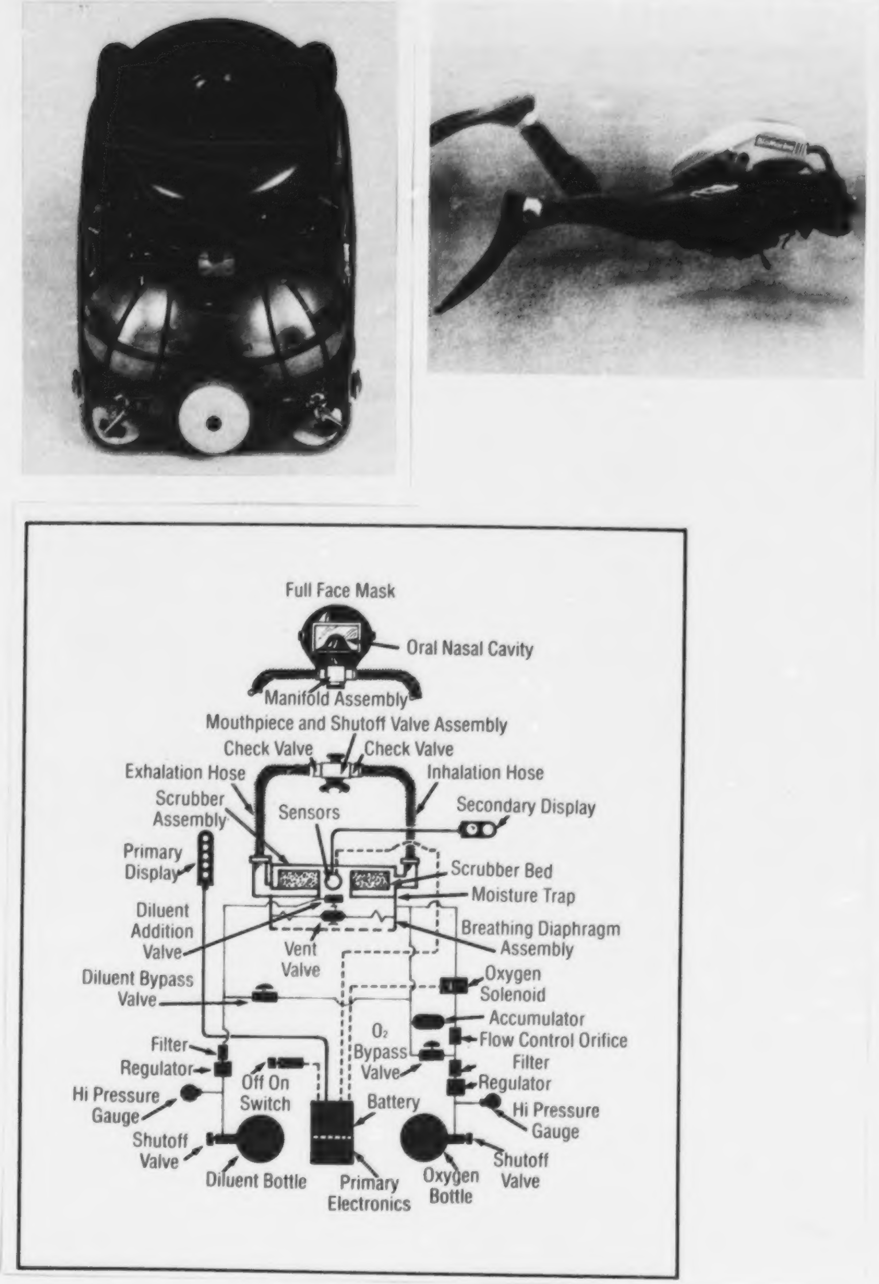

Figure 11.4 Closed-Circuit Mixed Gas SCUBA

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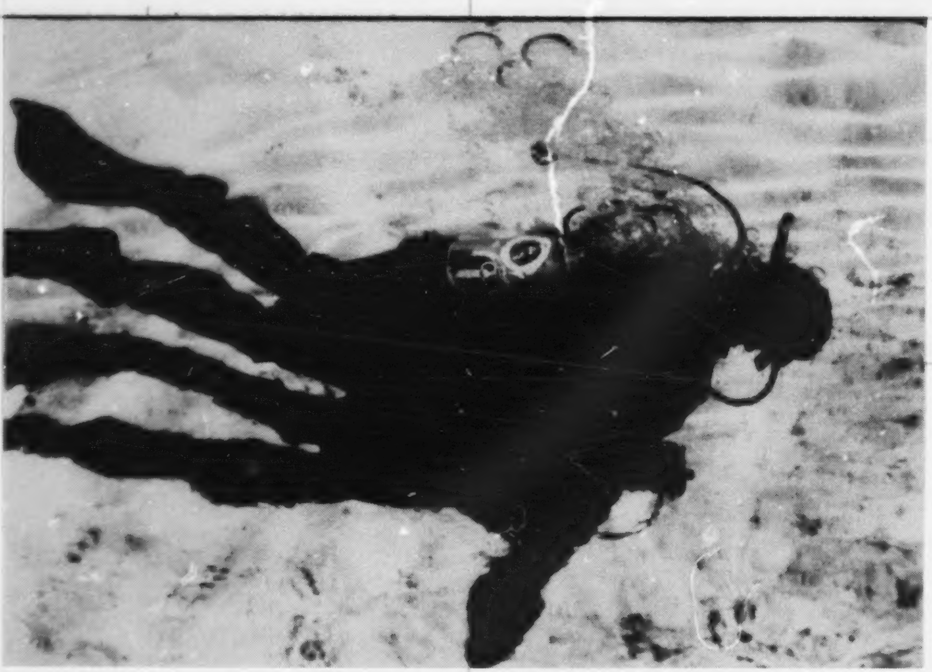

Figure 11.5 Open-circuit self contained underwater breathing apparatus (SCUBA)

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stage regulator reduces the intermediate pressure to ambient and opens only when the diver inhales. The diver exhales into the second stage regulator where the exhaled air passes through a check valve into the surrounding water.

The diver's eyes and nose are covered with a face mask which normally consists of a tempered glass plate mounted in a soft rubber frame held against the face with a rubber strap. An alternate face mask consists of a full face covering with some means of attaching the second stage regulator. This attachment generally takes one of two forms. In some full face masks the regulator mouth piece is removed and the regulator is attached directly to a port in the mask. Air is fed either to the complete mask or to an oral-nasal mounted inside the mask. In other full face masks, after the second stage regulator is mounted to the mask, the mouth piece is reattached to the part of the regulator that protrudes into the mask. Most masks in use allow the diver access to his nose without flooding the mask so he is able to pinch his nostrils to equalize pressure against his ear drums.

The self-contained diver generally weighs slightly more than the water he displaces and, therefore, is negatively buoyant. To control this situation, he wears a weight belt and a buoyancy compensator (BC). The BC is a sophisticated life vest, capable of oral and automatic inflation underwater. The diver inflates the BC sufficiently to bring himself to neutral buoyancy. Upon descent he must add air and upon ascent he must vent air to remain so. The purpose of the weight belt is to extend his buoyancy dynamic range (and to give him negative buoyancy if he is one of those individuals who is naturally positively buoyant).

Diving Dress

The two basic categories of diving dress are functions of the kind of diving being performed. Underwater work falls into either a non-swimming or a swimming mode. What the diver wears is, therefore, dependent upon whether or not he is swimming.

Non-swimming diving dress. The non-swimming diver is usually involved with heavy underwater work. Heavy work almost always is associated with massive structures where the diver's primary consideration is protection from abrasion and other physical injuries resulting from his coming into contact with what he is working on. The usual diving dress in these circumstances is a heavy, rubberized canvas outfit as shown in the MK-5 rig in Fig. 11.3. Weighted boots and a heavy harness are usually part of this outfit. Gloves may or may not be attached. Where they are not, rubber cuffs seal the wrists. In some cases the neck of the suit is attached to a heavy collar that is attached to the helmet, allowing free communication of air between suit and helmet. Otherwise, there is a rubber seal at the neck and a snap-ring device that connects the helmet neck to the suit neck. In this version, air from the helmet does not enter the suit, and air for the suit must be supplied separately.

The constant volume suit is distinguished from the variable volume suit by what happens to the suit when it receives air. Upon being filled with air, the rubberized canvas suit discussed above will distend to whatever its normal dimensions are. The suit becomes somewhat rigid at this point, and overpressurizing the suit will make it more so. Because the internal volume of this suit does not change, it is called a constant volume suit. A variable volume suit is made of a material that stretches. It usually is much more pliable than a constant volume suit. In normal use enough air is injected into the suit to lift it off the body sufficiently to allow the diver to be comfortable. Because the suit stretches and shrinks with increasing and decreasing internal pressure, it requires much less attention on the diver's part and generally is much more comfortable to wear. A variable volume suit must always be supplied with a source of air. There is a third type of suit that falls between the two just discussed. These suits are somewhat stretchy, and thus not constant volume suits, but not nearly so stretchy as variable volume suits. Suits in this category are called variously by either name, depending upon the manufacturer.

In practice the constant volume suit usually is used with the heavier (and normally older) hard-hat rigs. The variable volume suit is found more often with the newer, lightweight hard-hat rigs and with band masks.

Swimming diving dress. The swimming diver's primary clothing consideration is mobility, and his diving dress reflects this. Where conditions allow, the swimming diver will wear no diving dress at all. Environmental conditions determine what he wears when the water is not warm and pleasant. There are two basic categories, the wet suit and the dry suit.

The wet suit is constructed of a formfitting, closed-cell foam neoprene rubber material which usually is sandwiched between an inner and an outer layer of nylon fabric. Some suits have the nylon on the inside only, and some do not use the nylon fabric. Although the nylon protects the suit's outer layer and eases donning the suit, it also makes the suit less flexible. Suit material ranges in thickness from 1/16-inch to 3/8-inch. The thicker the material, the warmer the suit is. Suits generally have one to three pieces, not counting foot, hand, and head covering. The two- and three-piece styles consist of pants which may stop at the waist or be bibbed, an optional inner vest, and a jacket. The one-piece suit is like a jumpsuit with a slide fastener up the front or across the shoulders. Suits may have attached or separate boots, always have separate gloves or mitts, and may have a separate or an attached hood. The wet suit offers time limited protection against cold only.

The dry suit originated as a watertight rubber suit worn over a diver's insulating garment. The air inside it would compress with depth and the diver could experience suit squeeze, a condition where his skin is severely pinched between clothing folds. A recent development is an outgrowth of the variable volume non-swimming dress discussed above. As in the above case, there are constant volume, variable volume, and halfway between versions.

The constant volume dry suit is a lightweight suit constructed of rubberized material designed to retain the flexibility required by a swimming diver. These suits are designed with an inlet air valve controlled by the diver and an exhaust valve. The exhaust valve always can be manually operated, but in some suits there is also a provision for automatic operation so that the suit will vent as the diver ascends from deeper to shallower depths. These suits usually have boots attached; however, they can be obtained with ankle seals and separate boots. Gloves are always separate, but in some versions the gloves can be attached to cuffs on the sleeves via rings so they form an integral part of the suit. There are rubber seals at the wrists. Hoods may or may not be attached. Where they are not, the suit has a rubber neck seal. Where they are, the suit may or may not have a neck seal, depending upon the design of the hood. In some versions the hood can be attached to the suit in a manner similar to attachable gloves, by clamping the suit and hood material between a rigid under-ring and a clamp ring, giving the suit greater versatility in use.

The variable volume dry suit can be constructed of the same closed-cell foam neoprene as wet suits. As in the non-swimming dress previously discussed, they differ from the constant volume suits in that they stretch when filled with air. Since they are constructed of the same material as wet suits, they have all the insulating characteristics of the wet suit without the discomfort of being wet. And since the diver remains, for the most part, dry, body temperature is not lost as quickly to the surrounding water.

Newer variable volume dry suits are now being manufactured that are constructed of crushed foam neoprene. This type of suit has fewer insulating qualities, but is much tougher and more flexible than the older style suit. In cold water, insulating garments must be worn underneath this suit.

Another variety of variable volume dry suit is constructed of rubber. (See Figure 11.6) It has no insulating qualities at all and requires that insulating garments be worn beneath the suit even in moderately cool water, but it is the most flexible of the suits.

Seals at neck and wrist of the variable volume dry suits are the same as for constant volume suits. Design of boots and hood is also the same for both types of suits. The only distinguishable difference between these suits is the inherent stretch of the variable volume dry suit, and in the case of the neoprene suit, its inherent insulating ability.

Most of the dry suits have in common some form of waterproof slide fastener with a very few where entry is made through a very stretchy neck opening. Regardless of whether the suits are constant or variable volume (or one of the halfway versions), they tend to be either bulky in design with a lot of internal volume, or snug-fitting in design. The snug-fitting suits usually have an across-the-shoulder entry. The bulky suits have several different entries. Some start near the crotch in front and go up around the neck and back down to the crotch in front. Some begin at the middle of the back and go through the crotch to the chest. Many have an across-the-shoulder entry just as in the snug fitting suits. And a few are entered through the neck opening which stretches sufficiently, with the help of two or three tenders, to allow the suit to be pulled up over the diver's legs and torso.

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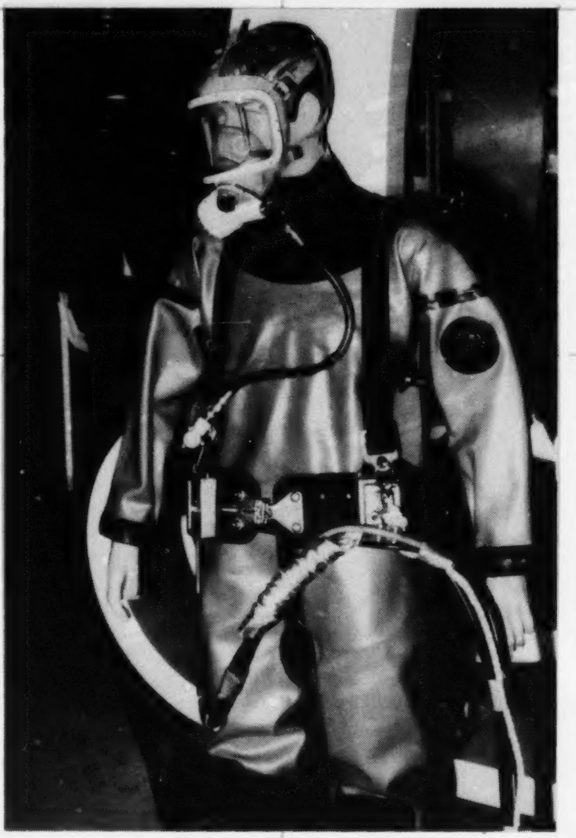

Figure 11.6 - Viking Variable Volume Heavy Duty Dry Suit with Surface Supplied AGA Mask

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SECTION 12

PROTECTION USING SELF-CONTAINED APPARATUS

The small group and the sport diver are left with only one option if they would dive in contaminated water--SCUBA. Unfortunately, neither standard SCUBA equipment nor available hybrids can adequately protect the free-swimming diver, and so he risks the consequences of becoming contaminated.

The limitations of standard SCUBA are self-evident. The diver's air is supplied through a second stage regulator mouthpiece clenched between his teeth. His mouth regularly is exposed to the water. Even if he takes great pains to preclude water entry into his mouth, the action of inhalation creates a slight negative pressure in his mouth, making it nearly impossible to keep water out. As in the band mask, small droplets are formed which the diver then inhales. The only way a SCUBA diver can clear condensation from the inside of his mask is to flood it with surrounding water, so his nose and eyes also become exposed to contamination. The standard SCUBA rig simply is inadequate for protecting the SCUBA diver from the effects of diving in contaminated water.

Hybrid arrangements of equipment offer little better protection. A full face mask mated to a second stage regulator eliminates the problem of water entering the mouth directly, but the droplet problem still exists. The mask negative pressure at each inhalation still is a regular source of water. Most full face masks still require condensation removal by flooding.

A SCUBA diver can protect his body and head (including ears) with a dry suit; but at best, his neck, face, stomach, and lungs will still be exposed to whatever is in the water, with the subsequent risk of contracting one of the diseases listed in Table 5.1 on page 5-2.

Protection Requirements for SCUBA Diving in Biologically Contaminated Water

A surface-supplied diver can be protected from contaminated water when the need arises. Simply stated, he is completely isolated from the water and so protected from it. The SCUBA diver has not had this option available to him, but essentially his requirements are the same.

The SCUBA diver's air supply must be isolated from the surrounding environment. From the time the air leaves the diver's tank until it reaches his alveoli, it must not come into contact with the surrounding water. Since the SCUBA diver's air supply is limited, the open circuit or free-flow method of pressurizing his mask cannot be used; however, a method must be devised to prevent the influx of water into the mask. This is the primary requirement. Should the diver inhale droplets of contaminated water, all other efforts of containment would be futile.

The diver's entire body not covered by the face mask must be isolated from the surrounding environment. There are circumstances where the hands may be exposed (so long as they can be decontaminated later); however, this should be an option--full body coverage capability is necessary. This body covering should not unduly restrict the diver's ability to move and work underwater.

The diver must have the ability to adjust his buoyancy, either with the suit directly, with an auxiliary buoyancy device, or with a combination of both. This buoyancy mechanism must not restrict the diver's ability to move and work underwater.

The equipment should be available off the shelf with little or no modification required to make it functional for use in biologically-contaminated water. Ideally, it should be within a reasonable price range affordable by the small group or the sport diver. It should be simple in design for ease of maintenance, and simple in use for ease in training.

And finally, the equipment must not pose a greater threat to the diver than would exposure to the contaminated water.

In summary, the diver's air supply and his body must be isolated, he must be able to work competently and safely in the equipment, and the equipment must be simple, convenient, inexpensive, and available.

SECTION 13

SELECTION OF SPECIFIC SELF-CONTAINED EQUIPMENT AND PROCEDURES FOR BIOLOGICAL HAZARDS

The selection of this self-contained equipment to protect divers from biological hazards was based upon a series of rigorous tests, together with the stipulations that the diver be able to perform work tasks competently and safely in the equipment, and that the gear also be relatively simple and convenient to service, wear, and operate.

Specific controlled tests were run for the Poseidon Unisuit, the Imperial Bubble Suit, the Poseidon Jet Suit, and the Viking Suit. A total of 1,140 recorded dives were made during the NOAA study (4) along with approximately 60 unrecorded dives. Helmets evaluated were the AGA Divator System, the Kirby-Morgan Band Mask, and the Superlite 17.

The AGA Divator Rig. A significant portion of the testing was performed to gain an understanding of how the complete AGA Divator rig would be suited for polluted water diving. The rig is adaptable to a surface supply umbilical, so this aspect also was tested.

The AGA Divator full face mask, as shown in Figure 13.1, is outfitted with a skirt and inner oral nasal manufactured of a special rubber that is soft, rugged, and light-weight, yet impervious to seawater and to extremes of cold and limited chemical concentrations. It has a built-in second stage regulator equipped with a safety pressure device that creates a safety pressure inside the mask. When the safety pressure is turned on by rotating the valve cover toward the diver, a pressure of about one inch of water column over ambient pressure is maintained within the mask. This safety pressure seals a reverse lip at the skirt of the mask, creating a positive and comfortable seal against the facial contours. It also precludes in-leakage and, according to the manufacturer, assures that the mask is self-purging should it become necessary to remove it and put it on underwater. With the safety pressure on, it is nearly impossible to accidentally have the mask removed underwater, making it unlikely that it would ever be knocked off by bumping into an object or by a high current.

The faceplate consists of an extremely wide-angle, high-impact polycarbonate having the same refractive index as water. Peripheral vision is exceptional; however, there is a pronounced "aquarium effect" where the side panels meet the front plate. Some of the masks used during these tests had the side panels roughened up with sandpaper on the inside to eliminate this effect. The mask accommodates wireframed glasses without modification. It has a removable o-ring sealed cover plate for installation of a microphone.

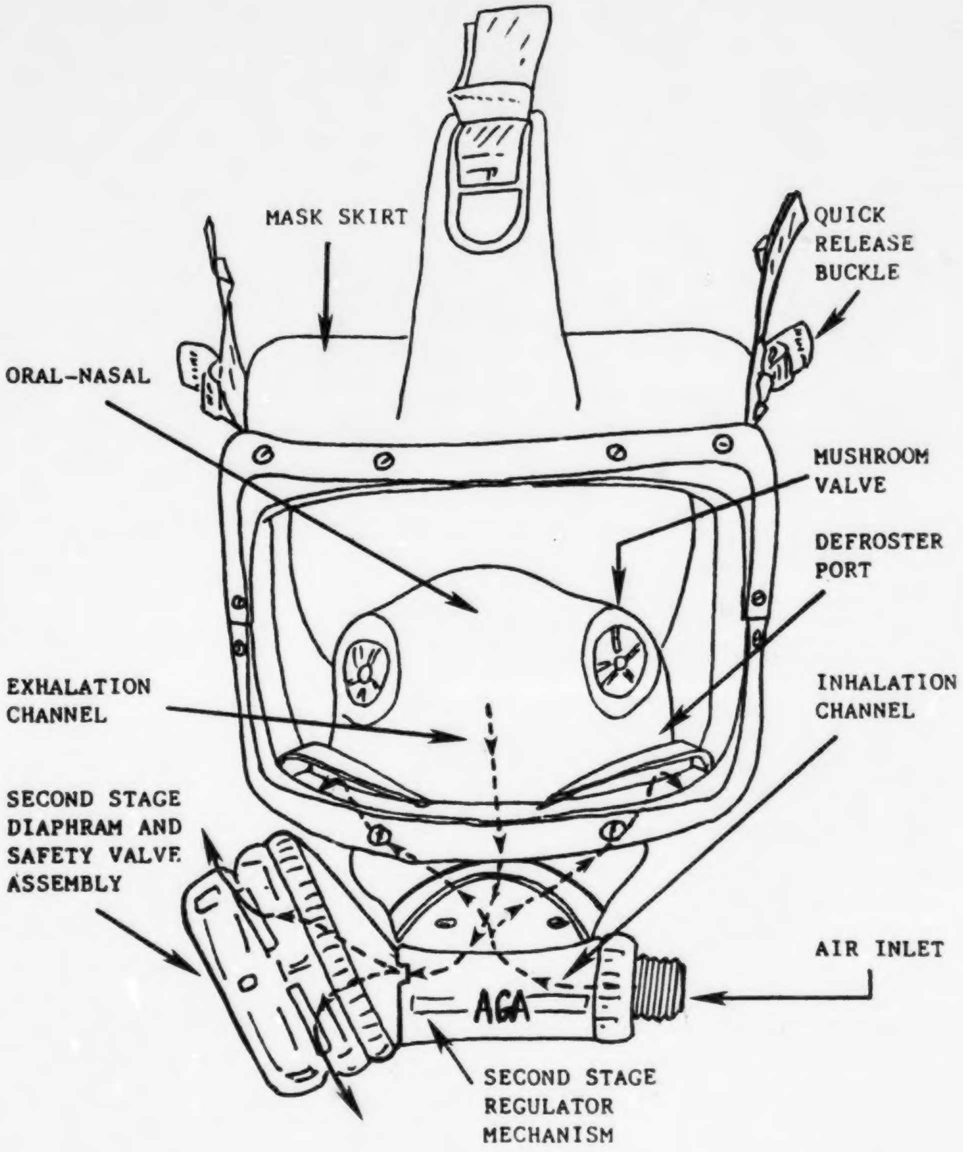

Figure 13.1 AGA Full Face Mask

The AGA Divator also incorporates separate inhalation and exhalation channels to minimize carbon dioxide build-up inside the mask. Inhaled air crosses the faceplate, becoming moisturized as it clears the faceplate, and enters the oral-nasal through mushroom valves. Exhaled air passes directly through the oral-nasal into the exhalation channel, and through a one-way valve into the water. Because of the positive pressure inside the mask, water is unlikely to backflow through the one-way valve. This feature, more than any other, was why the NOAA Report considered the AGA Divator such a good prospect for biologically-polluted water diving use.

SCUBA second stage regulators normally are supplied with air from the first stage regulator at about 140 psi above ambient. The AGA first stage supplies the mask with only 90 psi. This first stage regulator is specifically designed to mount beneath two small inverted air tanks and is not well-suited for mounting on standard SCUBA tanks. Most of the testing, therefore, was accomplished with standard tanks using first stage regulators that had their secondary pressures reduced to 90 psi. The AGA first stage regulator, however, also accommodates a surface-supplied umbilical, so tests were run with the complete AGA Divator rig. In addition to reducing the secondary output pressure of these standard first stage regulators, they were freeze protected. This amounts to filling the pressure-sensing mechanism with silicone fluid and sealing the opening with a flexible rubber cap. In this way the pressure sensing mechanism is isolated from contact with the water, but it can still transmit a pressure signal to the control mechanism. Kits for making this modification usually are supplied by the regulator manufacturer.

There is a pressure sensing mechanism inside the AGA Divator first stage regulator that will keep the diver breathing umbilical air so long as it is supplied at a pressure greater than 90 psi. As discussed in the previous section, however, pressure greater than 110 psi will break the pressure-balancing diaphragm inside the second stage mechanism. When the umbilical pressure drops below 90 psi, the regulator automatically switches to the tanks, and the diver does not know this is happening. During field tests in this mode, occasionally a diver found his tank pressure much lower than it should have been when he switched to his tanks. The reason was traced to this phenomenon. To prevent this during the tests, the AGA tanks were secured by the diver until he actually needed them. This turned out to be practical and easy to do.

During early dives with the complete AGA Divator rig, divers found they were excessively heavy. It was determined that when the AGA tanks are filled with air they are 19 pounds negative in fresh water. This implies that a wet-suited diver needs no extra weight when diving with this rig, and a dry-suited diver can use 19 pounds less than he normally would use. This results in an extremely comfortable dive, especially when diving in a non-neoprene suit.

During an evaluation dive, the diver descended on surface supply and at depth he switched from umbilical to tanks. Very shortly thereafter he experienced heavy breathing resistance. He commenced immediate ascent to the surface. By the time he had reached the surface, he could get no air at all from the mask, yet his tank gauge showed nearly 4,000 psi in the tanks. In the field this could have been a potentially disasterous problem, although it was easily handled under the controlled circumstances of the in-depth study.

A detailed look at this problem determined that water from a previous dive which had found its way inside the AGA first stage regulator had not been completely removed by the five minutes of free-flow. It had penetrated around the main valve spring where it was isolated from umbilical air flowing through the regulator. When the diver disconnected his umbilical and switched to his tanks, water around the main spring was distributed throughout the regulator by the high-pressure tank air flowing past the spring. The adiabatic pressure change dropped the regulator body temperature below freezing, and the entire regulator became clogged with ice.

This seems to be a design defect of the AGA Divator first stage regulator, since there appears to be no way to get water away from the main spring without using tank air which immediately freezes up the regulator. This problem effectively precludes its use for combined surface-supply and SCUBA operations except under carefully controlled circumstances where there is absolutely no chance of water getting into the first stage.

AGA Divator and dry suit compatibility. The AGA Divator seats against the face with a broad, turned inward skirt. The internal safety pressure assists in making the seal. Dives were made with the mask seal against the face and the hood seal against the mask, and the other way round. Some face seals had been modified so that they made a good seal with the outer side of the AGA Divator mask. Some of the face seals were designed with a smooth rubber surface facing out so that the mask could make a good seal against it. Thus, the two basic configurations were mask outside of hood, and hood outside of mask.

The AGA Divator conformed well to most facial contours and so generally made a good seal against the face. In cases where the diver's facial contours or his facial hair interfered with a complete seal, air leaked out from around the mask. With the hood outside the mask, the hood filled with air. For divers experiencing this problem, it was found that the hood made a better seal against the face than the mask did . These divers were more satisfied with the mask against the outside of the hood seal. In cases where the hood seal outer surface was nylon, there was a continual stream of air leaking from around the mask. Where the hood seal outer surface was smooth rubber, the mask made an effective seal against the hood and there was no leakage of air.

Future suits should be obtained with a smooth rubber outer surface on the face seal, and the mask normally should be worn against this surface.

The AGA Divator mask can be made compatible with all types of dry suit hoods. The ideal arrangement, however, is a hood face seal with a smooth rubber outer surface against which the mask seals.

The summary of the AGA Divator evaluation and testing is as follows:

1. Any first stage regulator from the top list in the Navy Experimental Diving Group regulator study (Middleton, 1980) can be used to supply the AGA Divator mask. Care must be taken to ensure that the regulator, adaptor fitting (if any), and hose are compatible. The regulator must have its secondary output pressure reduced to 90 psi, and the pressure sensing mechanism must be freeze-protected.

2. The complete AGA Divator rig, including mask, first stage regulator, tanks, and backpack, is compatible for polluted water diving, but there are certain drawbacks. The unit cannot be used in the combined surface supply-SCUBA mode without very special precautions. The suit air supply must be thought out in advance, and care must be exercised to ensure that fittings are compatible. An appropriate charging source for the tanks also must be available for full utilization of the rig.

3. A flooded AGA Divator mask will dewater itself automatically if proper procedures are used; however, the diver should be trained and practiced in these procedures. It is unlikely that the mask will become dislodged or knocked off accidentally.

4. The AGA Divator mask can be made compatible with all types of dry suit hoods. The ideal arrangement, however, is a hood face seal with a smooth rubber outer surface against which the mask can seal.

5. When used with an AGA Divator, snug-type dry suits consume about one-third less air than do bulky-type suits. Bulky-type non-neoprene suits consume about one-third more air than do bulky-type neoprene suits.

The Kirby-Morgan Band Mask

The lightweight diving outfit is surface-supplied with air for breathing, but unlike the deep-sea outfit, it does not admit air into the diving dress for buoyancy control. Diving which uses lightweight equipment is limited in depth, depending upon the equipment being used.

If the KM Band Mask or USN MK 1 shown in Fig. 13.2 is used, depths are limited to 130 feet (39.6 meters) without the support of an open bell and 190 feet (57.9 meters) with a bell. The basic components of a lightweight outfit are:

> The mask group which includes all valving. There are two different models of lightweight masks--the standard or "Jack Browne" rig, which is not suitable for polluted water operations, or the KMB Mask and USN MK 1.
>
> The diving dress group, which includes the diving dress (with two styles, wet or dry, available), and gloves, shoes, chafing pants, weighted belt, and knife.
>
> The hose group, which includes the air hose and fittings, lifeline, communications cable (if applicable) and the pneumofathometer.

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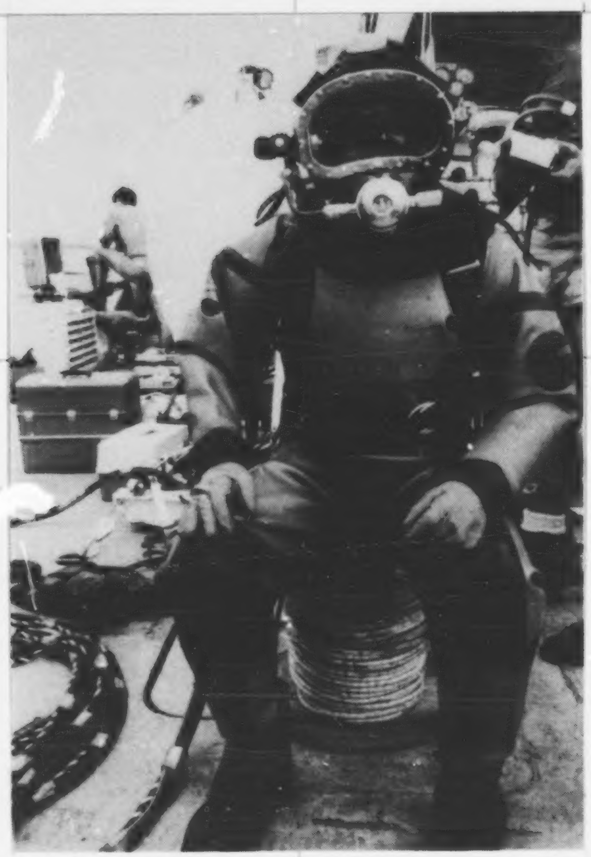

Figure 13.2 Pathogenically Protected Diver with Heavy Duty Viking Dry Suit and Surface Supplied Kirby Morgan Band Mask

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The Band Mask is an improved version of the standard lightweight mask. It permits two-way voice communication between the diver and the surface, and it has features that minimize the dangers of flooding, face squeeze, and CO_2 buildup. The mask is basically a demand breathing apparatus, but incorporates an emergency free flow capability for defogging the faceplate. This free flow may also be used as an emergency breathing mode or for clearing the mask when flooded. The demand regulator is manually adjusted during a dive to accommodate changing overbottom pressures supplied to the mask. It can be adjusted to provide continuous flow through the oral-nasal mask should a specific operational dive scenario require this. The mask, however, is basically a demand mask and provides all the air required by the diver when used in the demand mode; the above "dial-a-breath" and emergency free flow are not routinely utilized. For added safety beyond 60-foot depth usage, the mask is equipped with a backup air supply bottle commonly referred to as a "come home bottle," or "pony bottle."

The band mask is built around a molded plastic frame upon which are mounted a rubber face seal, a head harness, a faceplate lens made of 1/4-inch acrylic plastic, a side block assembly, a demand regulator and a moveable nose pad, which can be used by the diver as an aid in clearing his ears and sinuses.

-- Side Block Assembly -- This assembly functions as a manifold. It is fitted with an on/off defogger valve, which controls a steady air flow into the mask and across the inside of the faceplate. This feature is also used as an emergency breathing mode in the event of demand regulator failure. The emergency breathing supply valve for the come home bottle is located on the rear of the side block. The non-return valve is located within the side block assembly.

-- Demand Regulator -- The demand regulator is set into the mask in front of the diver's mouth. This regulator is similar to the second stage of a single hose SCUBA regulator. Air passes to the demand regulator from the side block assembly through a hard pipe; the flow of air is controlled by the diver's breathing rate. A manual purge button permits the diver to establish a free flow through the regulator. The regulator is adjusted by a knob on its side to accommodate air supplied at overbottom pressures as necessitated by operational requirements. The knob can be opened slightly to permit a free flow through the oral-nasal mask as discussed previously.

-- Emergency Air Supply -- The emergency breathing supply valve provides an air supply path parallel to the non-return valve. Threads on the inlet of this valve permit attachment of the "come home bottle" whip. The "come home bottle" is equipped with a SCUBA type first stage regulator.

-- Frame Exhaust Valve -- This is a mushroom-type valve which is located in the mask frame under the demand regulator. The exhaust valve is at the lowest point in the mask; therefore, when the mask is upright, the discharge through the valve automatically purges water from the mask. Under ordinary conditions, this valve accommodates the steady defogger flow.

-- Oral-Nasal Mask -- This unit is mounted inside the main body of the mask, an arrangement which reduces both dead space within the mask and the potential for CO_2 build-up. In normal demand operation, the air flows directly into the oral-nasal mask and is directed through the regulator exhaust. When emergency free flow, defogging, or venting is executed by opening the defogger valve, part of the flow enters the oral-nasal mask through a check valve in its wall and passes out through the regulator exhaust valve. The oral-nasal mask is a vital component of the MK 1 mask and must never be removed.

-- Communications -- Earphone and microphone assemblies are installed in the mask. Communication wires pass through a watertight fitting in the mask frame and are appropriately connected to internal terminal posts. Standard Navy amplifiers are compatible with this equipment.

The diving dress which has been utilized with the band mask includes the Unisuit, Viking Dry Suit, and standard wet suit.

A summary of the band mask test evaluations is as follows:

1. Demand mode, normally used for band mask operations, cannot be used for polluted water diving.

2. Open circuit mode is effective for polluted water diving, but only should be used with surface supply because of high air consumption.

3. Both Mod 1 and Mod 2, when coupled to a polluted water-modified hood, can be used for polluted water diving in either SCUBA or surface-supply mode.

Modification one (Mod 1) consisted of placing U.S. Divers' exhalation flutter valves over the exhaust tee ends to prevent backflow of water into the second stage regulator attached to the mask. The standard hood, which has a slide fastener from the top of the head down the back for ease of entry, was replaced with a hood minus the slide fastener. This was designed specifically for ease of mating to the neck seal using Viking neck clamps. Mod 1 was intended for SCUBA use in demand mode only except for occasional use of the defogger valve to clear the faceplate. During surface-supplied tests, both demand and open circuit were used.

Modification two (Mod 2) consisted of removing the second stage exhaust valve entirely, blanking off the opening, and reversing the mushroom valve through the oral-nasal so that air flow was from the oral-nasal to the mask instead of the other way around. In this configuration, breathing air could be obtained only through the demand valve. Air from the defogger valve could be used to clear the faceplate, but was not available for breathing. Hood modifications were identical to those for Mod 1.

The band mask is supplied from a first stage regulator just as standard SCUBA regulators are. The first stage regulator must be freeze protected as with the AGA Divator. During these tests, the U.S. Divers Conshelf and the Scubapro Mark 5 were used, but it must be remembered that the Mark 5 is difficult to freeze protect. The test dives were in clean water, so freeze protection was not critical, and the available supply of freeze protected first stage regulators was augmented by the MARK 5 regulators present.

During normal use, most divers put a small hole in the top of their dry suit and band mask hoods. While diving, air often escapes around the neck seal or face seal and accumulates in the hood. This hole serves to let that air out. This hole also lets water in, so this practice is unacceptable for diving in contaminated water. A provisional solution to this problem was found during the field studies. A Sea Quest BC overpressurization valve was installed in the hoods. The valve was fitted with the lightest spring available from Sea Quest, but when this proved to be too stiff, it was further reduced by clipping off various lengths until an apparently satisfactory size was found. BC overpressurization valves adjusted in this fashion were installed in all suit and band mask hoods.

4. When the modified hood is mated to a dry suit, care must be taken to ensure that the whole arrangement is not too tight. Removal of thick neoprene hoods from the dry suit, leaving enough material to mate with the band mask hood, appears to be the best solution where thick hoods cause excessive tightness.

5. Effective hood relief valve cracking pressure experimentally is less than 0.2 psi. The position of the spring within valve housing, or the valve housing used, is not a significant factor. Relief valve findings are sketchy, however, and more work is needed before further definitive statements can be made.

Recommended Diving Dress for Microbiological Hazards

The recommended system presented here is not the only solution to the problem of protecting a SCUBA diver from the hazards of polluted water. It certainly is not the best solution, for gaps still exist, and research still goes forward; but it is a working solution, one that the findings of this study clearly show adequately protects the SCUBA diver. It can be considered an interim solution for biologically-contaminated water, one that can be, and already is being used around the world where standard SCUBA techniques are inadequate, and where surface supply cannot be used.

One of the basic premises of this undertaking was that the final solution had to include equipment that was available off-the-shelf with little or no modification required to make it functional for use in contaminated water. Also, it had to be reasonably priced, simple in design, and easy to use.

There were two elements specifically required, a suit and a mask. The research turned up a generalized suit solution, and two mask solutions, one generalized, and the other brand specific, the preferred solution being the latter. Williscraft (15) went to great lengths to avoid specific brand endorsement or disparagement during this study, and the inclusion of a specific mask in the recommended solution should not be considered as an endorsement of the manufacturer's product; rather, it should be considered as an endorsement of the underlying principles the manufacturer chose to apply in the production of this particular mask. Any future mask appearing on the market which would possess similar characteristics would be equally acceptable after a suitable series of tests to ensure that it did not compromise the essential requirement--absolute exclusion of the outside environment.

The suit. The recommended suit is a "smooth skin" dry suit having the following characteristics: It must have an attached hood and attached boots, although the hood may be removable so long as it can be mated to the suit with a waterproof seal as in the Viking Suit. It must have a means of inflation from either the diver's air tanks or from an external "pony bottle." Care must be taken to ensure that any adaptors used in the inflation hose are flow matched to the hose. It must have a diver-controllable exhaust valve that keeps water out of the suit. The hood must have an installed relief valve that relieves automatically to vent off any air accumulating in the hood. And above all, the suit must keep the diver completely dry on a test dive in clean water.

A diver requiring hand protection can add special cuffs to his dry suit and attach heavy-duty rubber gloves with long cuffs to these suit cuffs. Attachment can be accomplished by slipping a short piece of plastic pipe over hand and wrist, and clamping the glove and suit cuff to this pipe section with a hose clamp. Care should be taken to ensure that the seams where the cuffs attach to the suit are genuinely waterproof.

The mask. The recommended mask is the AGA Divator mask coupled to any standard first stage regulator noted in the top listing of the Navy Experimental Diving Group regulator study (Middleton, 1980). This first stage regulator must have its secondary output pressure reduced to 90 psi, and it must be freeze-protected. Since the AGA Divator is manufactured to metric standards, and most of the first stage regulators on the Navy list are manufactured to U.S. standards, it may be necessary to use adaptors to connect the two items. Where possible, the AGA Divator hose should have its metric fittings removed and an appropriate fitting attached. Otherwise, care must be taken to ensure that the adaptors are flow matched to the hose. In use, the mask safety pressure must always be turned on.

The complete AGA Divator rig also is acceptable, provided appropriate means are used to supply air for suit inflation. This complete outfit, however, is quite expensive, especially when one considers the required ancillary equipment, so this solution does not really meet the originally-stipulated cost requirements.

It is possible that other manufacturers will choose to produce masks that, like the Divator, are internally pressurized to prevent in-leakage of water. When produced, such masks also will be acceptable provided inleakage is absolutely prevented. A particular point to watch out for is back-seepage around the exhaust diaphragm. In the Divator, this problem is circumvented by separating the inhalation and exhalation channels. Any new mask must solve this problem with equal success.

The other recommended mask solution is a band mask, Mod 1 or Mod 2. Mod 1 consists of attaching flutter valves to both sides of the mask exhaust tee. Mod 2 consists of removing the second stage regulator exhaust diaphragm and housing, blanking off the opening, and reversing the mushroom valve in the oral-nasal. For both modifications, the hood is replaced with one having no slide fastener and having a straight neck designed for attachment to the suit neck with a ring and clamp similar to the Viking Suit ring and clamp. The hood also must have a relief valve near the top set to release at no more than 0.2 psi.

The band mask is not the solution of choice, because, like the complete AGA Divator rig, it is quite expensive and, therefore, outside the originally stipulated cost requirements. Many diving organizations, however, already possess one or more such masks, and in this case, this solution is much less expensive than any other. It must be stressed that diver comfort is lower than with the AGA Divator, and the band mask configured for polluted water diving is more cumbersome to put on and take off. Diver abandonment of his breathing equipment underwater also is much more difficult with this equipment, but this action always should be considered as the very last resort in polluted water.

A final consideration when using a modified band mask for polluted water diving is that it may be necessary to remove neoprene dry suit hoods in order to make the rig sufficiently comfortable. Should this be done, enough suit hood material must be left to allow for mating of the band mask hood to the dry suit.

SECTION 14

MODIFIED SURFACE-SUPPORTED DIVING SYSTEMS

Draeger Constant Volume Suit

The Draeger Constant Volume Suit with neck entry emerged as a likely candidate for providing adequate protection in polluted water. Its thick, smooth neoprene surface can be decontaminated more readily than other dry suits. The hood fully encloses the diver's head, has the demand regulator built in, and seals to the suit at the neck entry point in a simple, reliable fashion, thereby eliminating the need for a water-tight zipper.

Early in the evaluation program, it became apparent that most exhaust valves in demand regulators allow a few small droplets of water to enter during the exhaust cycle. When the demand valve is activated, the jet of incoming air breaks up the droplets into a mist which is then inhaled by the diver. This normally is not noticed by the diver, and in clean water it is of no significance. Failure of the exhaust valve was also of concern.

To compensate for these weak points, the exhaust valve of a Scubapro MarK 5 demand regulator was eliminated and the valve port "blanked off" (Fig. 14.1). The pathway of breathing gas was then "in only" through the demand regulator and into the Draeger oral mask. A separate exhaust valve was mounted in the port which formerly contained the Draeger demand regulator. To eliminate "splash back" and to provide greater reliability, two exhaust valves were mounted in series, separated and sealed at each end by large "O" rings. Fig. 14.2 shows a breakdown of this series exhaust valve (SEV). Test dives with these modifications showed a slight but acceptable increase in exhalation resistance. The demand regulator will also freeflow slightly when the outlet of the SEV is higher in the water column than the demand regulator diaphragm.

To provide communications, a microphone and electrical penetrator were mounted in the plug provided on the right side of the Draeger hood. The earphone is mounted in an existing pocket on the outside of the hood. This configuration (Fig. 14.3) provides excellent communications with a minimum of penetrations into the suit. It can be used with hard wire or wireless systems.

Some divers experience difficulty in equalizing their ears during descent when using this apparatus. To assist divers in ear clearing, an ear equalization pad (Gaudiosi pad), made of foam neoprene, was glued into the lower portion of the mask. Fig. 14.4 shows the Draeger hood with all of the above-mentioned modifications and additions.

Suit-Under-Suit

Thermoregulation is a common problem in diving. Normally, hypothermia is the problem, and diving suits are designed to keep divers warm, either passively with insulation, or actively by passing hot water through specially constructed suits. NOAA divers have encountered situations in which significant overheating of the diver has occurred due to warm water and the necessity of wearing a dry suit for protection against polluted water. The "suit-under-suit" (SUS) was developed to allow heating or cooling of the diver, and to reduce the probability of contamination of the diver's body in the event of damage to the suit. (See Figure 14.5)

Dry suits containing air have significant internal/external pressure differentials, depending upon the position of the diver in the water. Since both a pressure differential and a hole are required for entry of water into a dry suit, elimination of one of these factors will eliminate entry of outside water. If the inside of a dry suit is filled with water, the internal/external pressure differential can be reduced or eliminated. This same water can be used for diver thermoregulation.

Fig. 14.6 shows the SUS. A tight-fitting foam neoprene undersuit with attached feet and neck entry makes up the innermost portion of this system. The neck of this suit seals to the neck ring of the Draeger suit. A neck dam provides a seal between the neck ring and the diver's neck (Fig. 14.7). The Draeger suit and hood seal is then made in a normal fashion over the SUS and neck dam. Clean water is pumped into the area between the SUS and the Draeger suit via the umbilical from the surface, and the water exits through the exhaust valves near the ankle of the Draeger suit. The neck dam prevents entry of this water into the hood.

The suit is filled with water while the diver is at the surface of the water with his feet in an elevated position to allow the escape of air through the exhaust valves. The diver must exit from the water slowly at the end of the dive to allow adequate time for water to drain from the suit. A two-way valve is provided to allow the diver to control the rate of flow through the suit, and to provide discharge of pumped water in order to maintain a rapid flow through the hose. The latter is sometimes necessary to maintain proper water temperature.

Test dives with this system proved to be significantly more comfortable for the diver than an air-filled dry suit. No pressure differentials exist, thereby eliminating suit squeeze. Buoyancy changes due to compression and expansion of air and air shifting within the suit are also eliminated.

Another feature of the Draeger hood that NOAA has modified is the hinged faceplate. The hinge normally allows the faceplate to be opened on the surface for the diver's comfort. It was felt that the danger of an accidental opening in the polluted water or leaks through the seal outweighed this short-term convenience. A new Lexan faceplate was machined to replace the original and is fitted into a recessed groove behind the opening for the original. This faceplate is held in place by the original clamp. This configuration has comfort drawbacks for divers with long noses.

Demand Regulator Mod. II

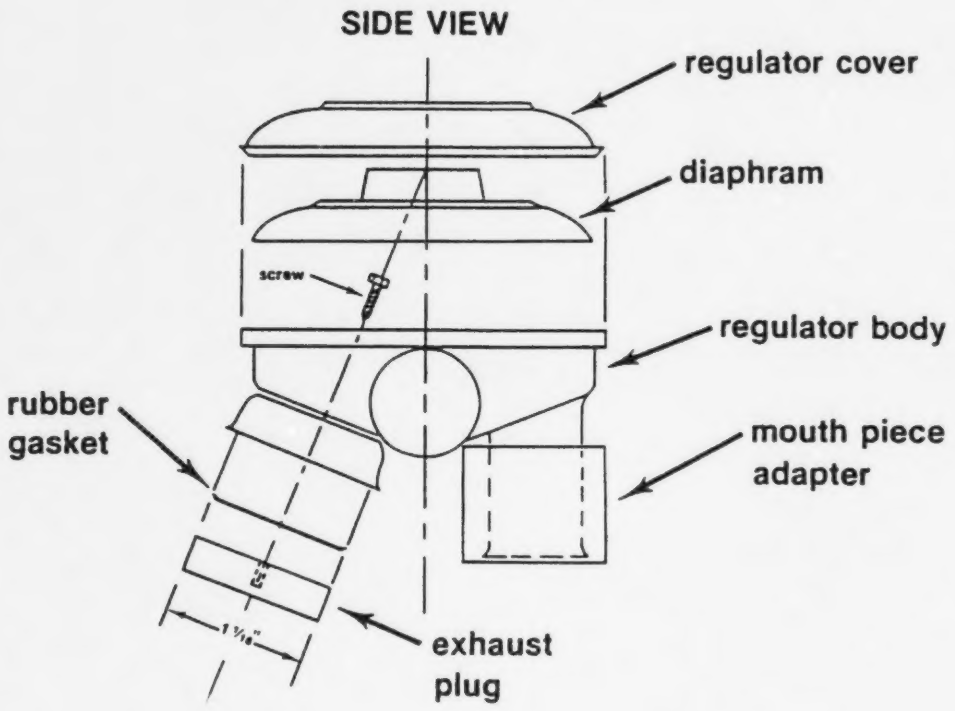
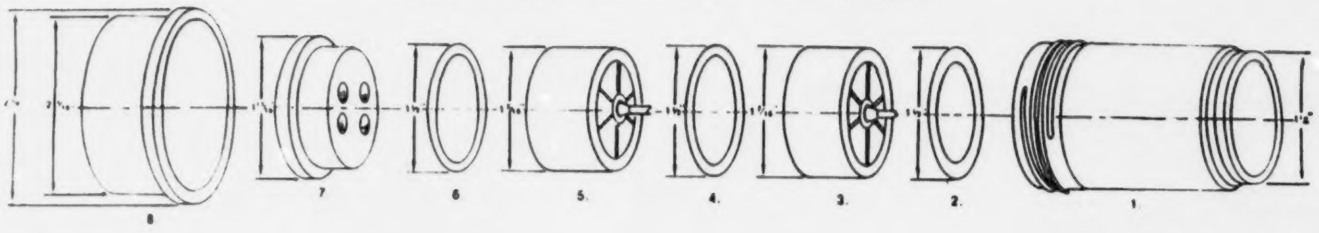


Figure 14.1

Series Exhaust Valve Mod. I (Breakdown)



1. Exhaust valve body
2. O-Ring (OD = 1 ½", W = 3/16")
3. Check valve body
4. O-Ring (OD = 1 ½", W = 1/8")
5. Check valve body
6. O-Ring (OD = 1 ½", W = 1/8")
7. Cap
8. Exhaust valve body cap

Figure 14.2

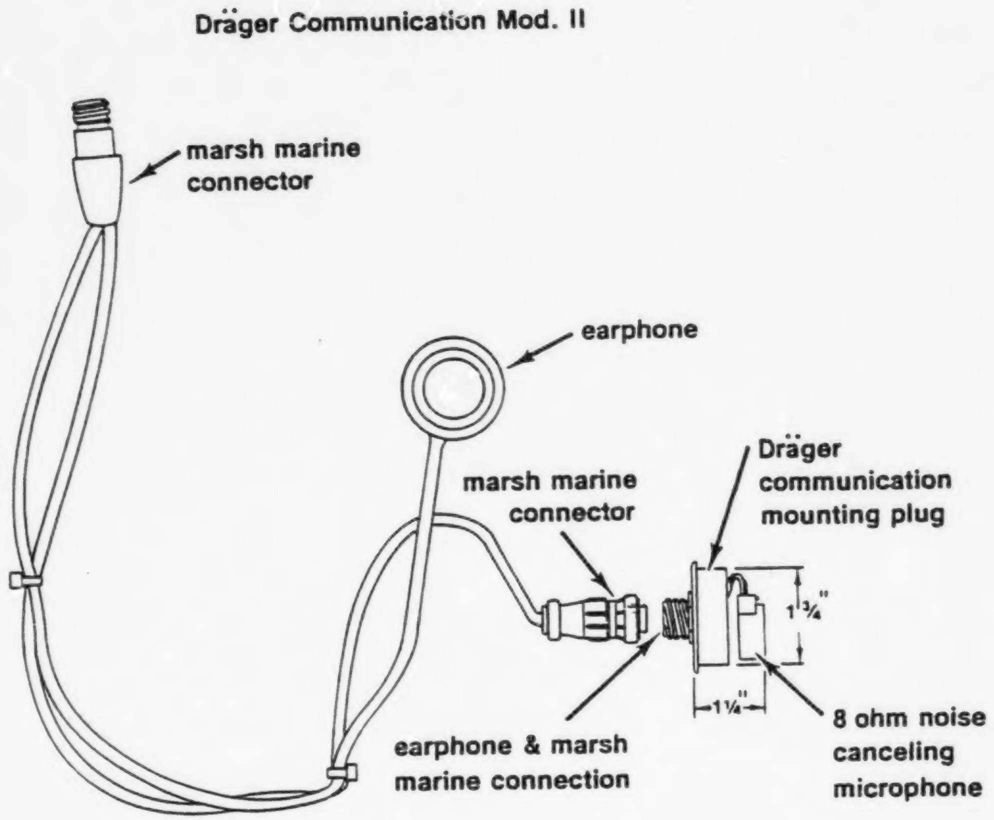

Dräger Communication Mod. II
marsh marine connector
earphone
Dräger communication mounting plug
marsh marine connector
1¾"
1¼"
8 ohm noise canceling microphone
earphone & marsh marine connection

Figure 14.3

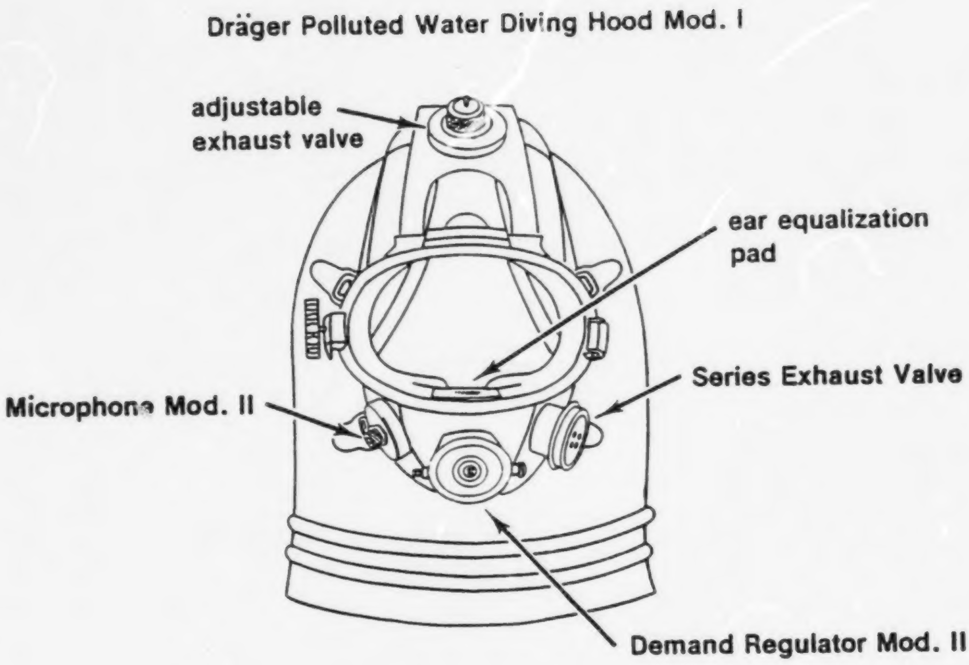

Dräger Polluted Water Diving Hood Mod. I
adjustable exhaust valve
ear equalization pad
Series Exhaust Valve
Microphone Mod. II
Demand Regulator Mod. II

Figure 14.4

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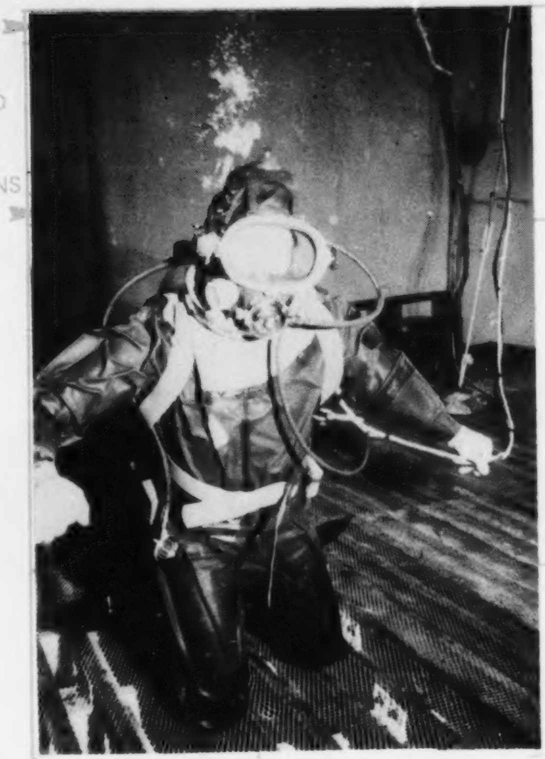
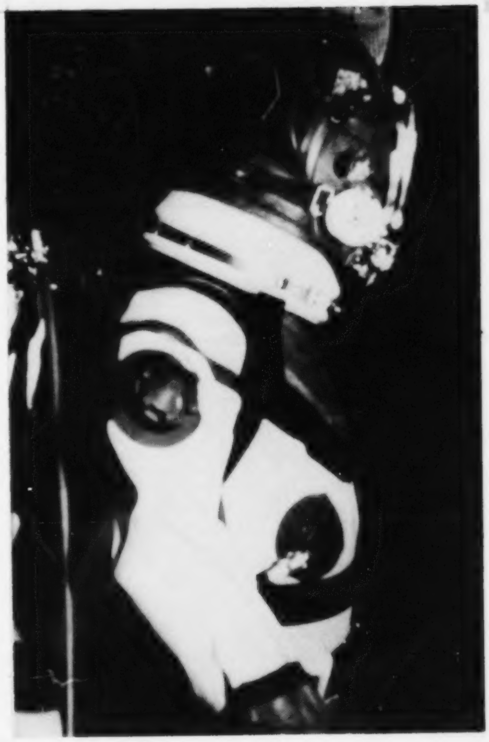


Standard Draeger
Hood and Suit



Draeger Hood w/Modified Viking
"Suit-Under-Suit" Dress

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Figure 14.5 - Draeger System

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Suit Under Suit (S.U.S.)

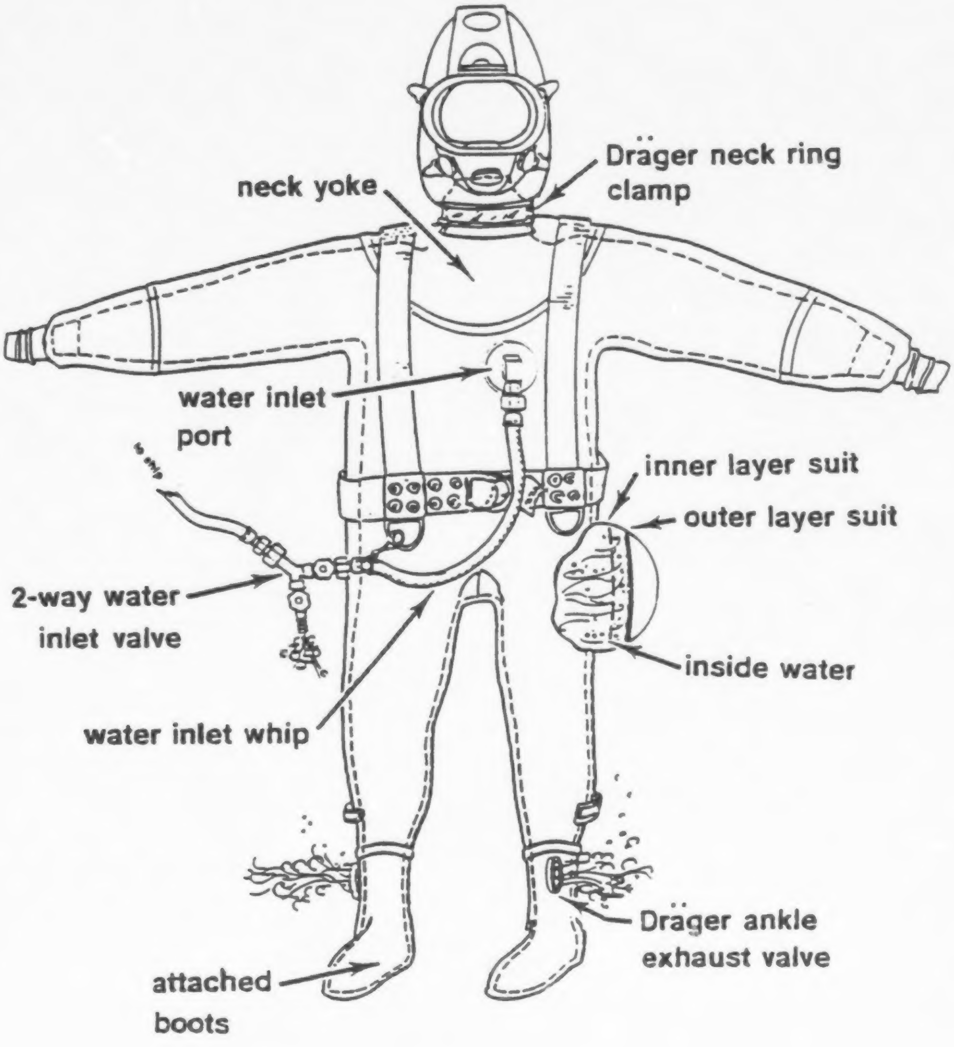

Figure 14.6

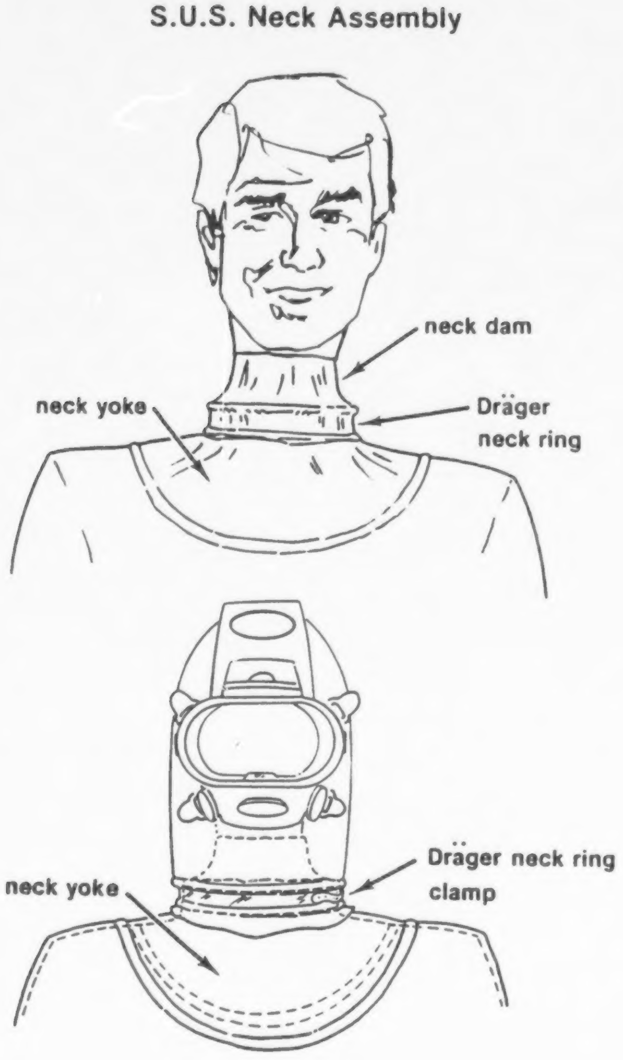
S.U.S. Neck Assembly
neck dam
neck yoke
Dräger neck ring
Dräger neck ring clamp
neck yoke

Figure 14.7

The MK-12 Surface-Supplied Diving System (SSDS)

The MK-12 SSDS as shown in Figure 14.8, consists of four major assemblies, the helmet assembly, the recircular assembly, the dress assembly and support equipment. The helmet may be used with air or mixed gas as the breathing medium, with the use of the recirculator as a modular, add-on component for mixed gas operation. The normal diving dress consists of a crushed foam neoprene nylon dry suit, outer chafing garment, jocking harness, lightweight diving boots, and gloves. Two-, four-, and five-pound lead weights (to a maximum of 60 lbs) fit into the calf, thigh, and hip pockets of the outer garment. The swimming dress consists of either a wet suit or swim trunks with jocking harness, fins, scuba weight belt or outer garment, and weights and the neck-dam with exhaust valve in the ambient configuration. All dress configurations require the use of the jocking harness to provide helmet stability.

The MK-12 SSDS air operations will support a diver performing tasks varying from light to heavy work to depths of 250 FSW. Operating the MK-12 SSDS with console overbottom pressure determined by hose length and dive depth provides the means of ensuring adequate airflow through the helmet. The MK-12 is an open circuit system in air operations. The air is supplied from the surface by the umbilical hose through a non-return valve within the air supply adapter, through stainless steel tubing to the air supply valve, and out into the helmet by means of the air supply diffuser. The air is directed up across the front viewport and toward the diver's face, exiting the helmet via the exhaust valve. In the adjustable configuration, the normal operating range of the exhaust valve provides a helmet pressure differential of 0.3 ± 0.05 psi to 2.0 + 0.3 psi with a flow of 6 ACFM.

The helmet shell is laid up with fiberglass cloth and polyester resin for a strong, light, impact-resistant structure. The shell is coated with a highly visible yellow gel coat to provide the U/W definition. A cast lead weight is cut to fit into the crown of the helmet, then laminated with fiberglass and resin. The weight is sized and located to make the helmet neutral in buoyancy and to counterbalance the weight of the base and breach rings. This makes the centers of gravity and buoyancy coincide, resulting in a stable comfortable helmet in all positions.

The standard diving dress is a commercially available drysuit modified to accept the MK-12 lower breach ring. It is made of 1/4-inch closed cell neoprene rubber-backed on both sides with nylon fabric. The seams curve around the legs to produce minimum stretching of the seams, reducing tension and consequently reducing the chance of leaks. The seams are butt-fitted, glued with neoprene cement, and covered on the inside surface with seal tape.

The outer nylon chafing garment serves several purposes. It provides protection for the dry suit against snagging, tearing, and abrasion; provides inflation restraint to prevent inadvertent flow-up, has pockets for installing diver weights, and aids in maintaining the jocking harness in place.

The standard MK-12 SSDS diving dress is virtually impossible to decontaminate and does not provide a dry suit/glove interface. As a result

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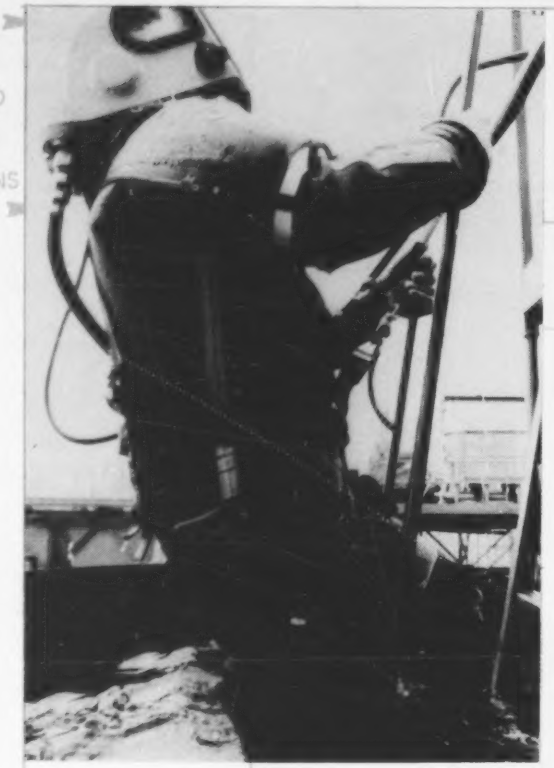
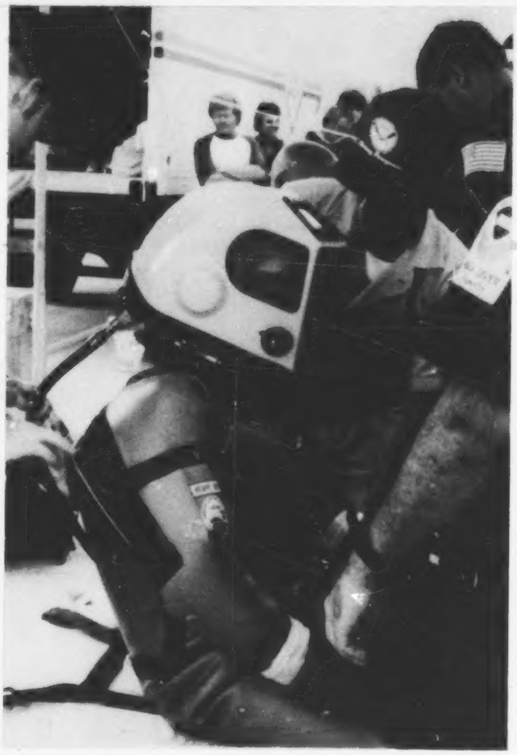
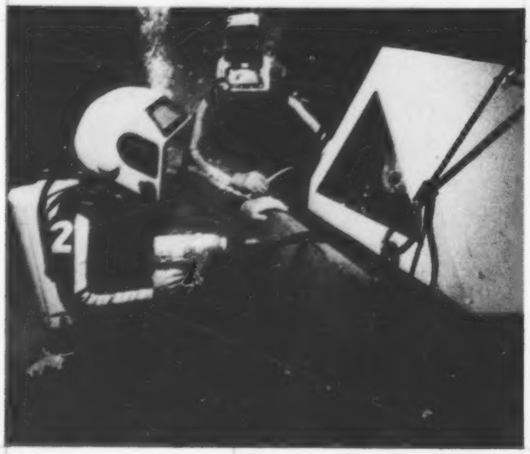


MK-12 SSDS and Modified
Viking Suit w/Weight Pockets



MK-12 SSDS and Modified Viking
Suit wo/Weight Pockets



MK-12 SSDS and Standard
Issue Foam Neoprene Suit and
Chafing Garment

Figure 14.8 Navy MK-12 Surface-Supplied Diving System (SSDS)

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of this situation, Viking Technical Rubber has produced two variations of the MK-12 diving dress as shown in Figure 14.8 which are very suitable for contaminated water operations. Each is delivered with the lower MK-12 helmet breach ring attached.

The first Viking suit model is an exact duplicate of the standard MK-12 outer chafing garment. This Viking dress provides all necessary weight pockets to accept the 60 pounds of lead bars, blocks, and rods required for diver buoyancy control. This suit also includes the compress, calf, and thigh straps to prevent diver "blow-up" or overpressurization.

The second Viking MK-12 model suit is a smooth dress with no weight pockets or compressive straps. This model requires the utilization of the standard outer chafing overalls.

The Viking suits are made of very heavy weight 1.1 mm thick natural rubber bonded onto polyester tricot fabric. The rubber provides the waterproofing but no insulation. The diver wears either clothing or insulated underwear for warmth. The thickness of these undergarments can vary with the water temperature expected. For especially cold water, Viking offers a jumpsuit made of 10 mm thick polyester foam, lined on two sides with nylon. This thermal underwear can be worn over a pair of long cotton underwear.

The design of the Viking suit has a number of advantages. Neoprene compresses at depth, becoming thinner and providing less insulation. The Viking, however, relies upon the air inside it and, especially, the undergarments, to keep you warm. As the air in the suit is compressed at depth and the suit begins to cling, you merely add air into it until comfortable. The Viking Suit has also been modified to function in the SUS mode as shown in Figures 14.9 and 14.10 and to mate with the MK-12 helmet.

The rubber surface of the Viking is smooth and not likely to snag on rocks and other sharp objects. It is also easy to decontaminate. The fabric-reinforced rubber doesn't stretch easily and won't balloon when air is added to the suit. The suit material is thinner than neoprene and takes up less space when rolled up. The entire suit fits into a carrying bag the size of the average knapsack (eight inches in diameter and 24 inches long).

Any suit is only as waterproof as its seams and seals. The seams of the Viking suits are sewn and then vulcanized under a rubber tape, making the whole suit basically one piece of rubber. This provides not only waterproofing but strength.

There are only four openings in the Viking suit: the neck, each wrist, and the back zipper. The boots are attached to the suit and are of the same material, only reinforced and bonded to a tough rubber sole complete with molded tread. An additional layer of rubber is bonded to the front of each leg running from just above to just below the knee as added chafing resistance.

The wrists of the suit are sealed by stretchy latex cuffs. These are cemented to the arms under rubber tape but can be replaced easily if damaged. Cuff rings are hard slipped inside the sleeve of each arm which

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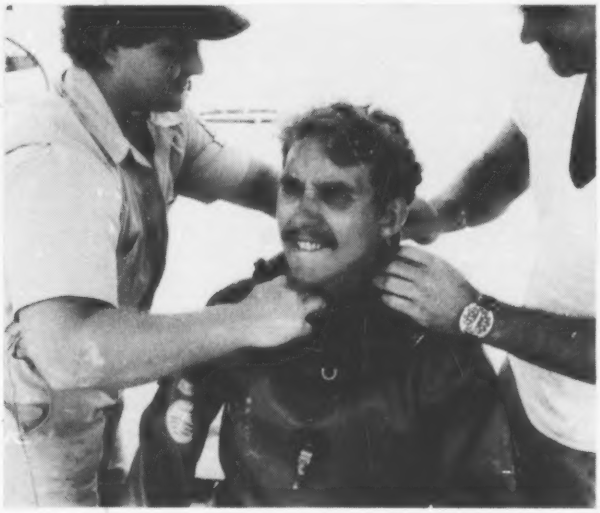
Donning Outer
Viking Suit Over
Inner 1/8" Suit



Mating Neck Ring For Inner
and Outer Suits

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Figure 14.9 Modified Viking "Suit-Under-Suit" for MK-12 System

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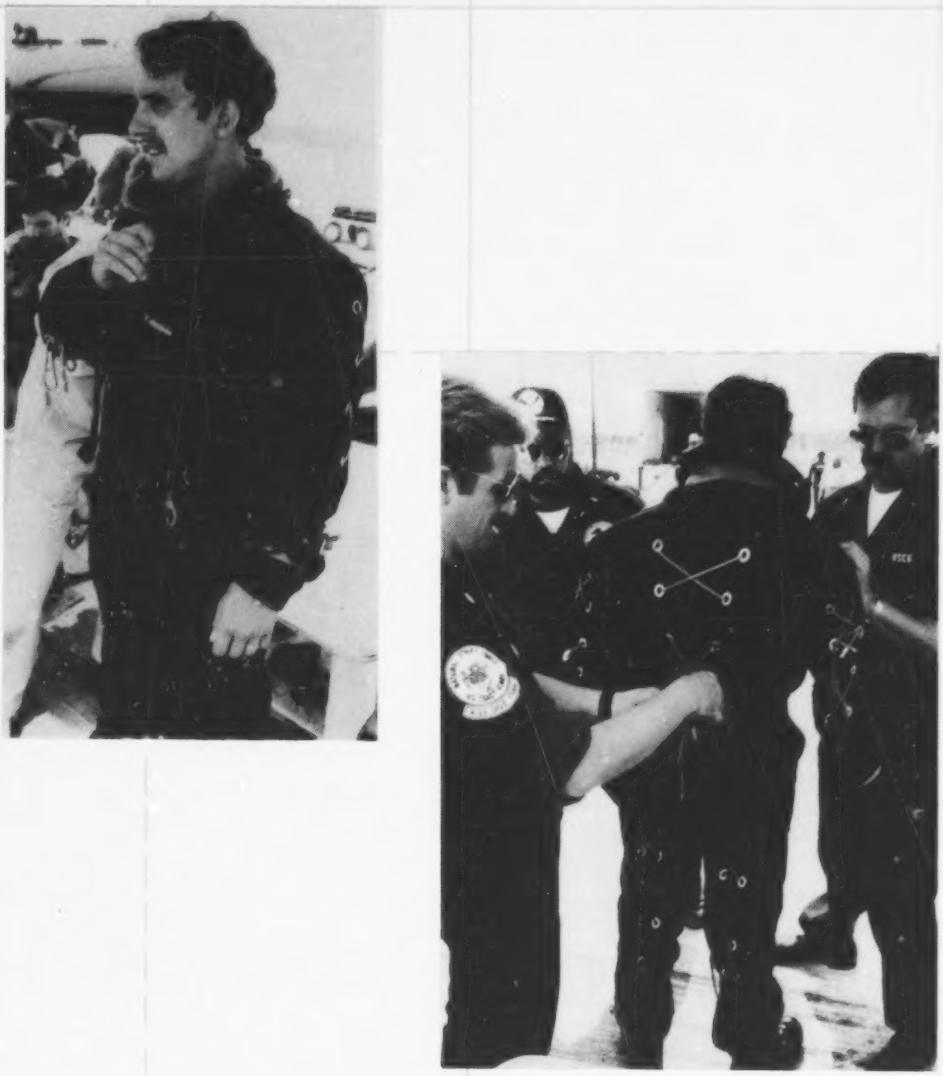

Figure 14.10 Outer Chaffing Garment for MK-12 Viking "Suit-Under-Suit" Dress

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allows for a multiple gloving system to be attached to the suit as shown in Fig. 14.11. A latex chemical-resistant glove is worn followed by a cotton work glove to detect any leakage from outer gloves and for warmth. Over the cotton glove is a heavy neoprene rubber glove which is covered by an outer cotton chafing glove for abrasion resistance.

The neck or collar of the suit is a tapered latex rubber tube. The tube can be trimmed as necessary for different neck sizes. This is important as excess pressure around the neck, even if bearable, can have adverse effects on a diver. Trimming the tapered neck tube should be done carefully to avoid accidentally over-enlarging it. The latex collar is surrounded by a latex hood and both are attached to the suit in the same manner as the cuffs.

The diver dons the Viking Sport through a heavy metal zipper on the back of the suit at the shoulders. When closed, the zipper is watertight.

The Viking suit can be adjusted easily for buoyancy by adding or venting air. Insulation is provided by undergarments. Air is added by a power inflator. A low pressure hose (provided with the suit) connects the regulator first stage to a valve on the left breast of the suit, allowing the diver to add air when this valve is pressed. Another valve, on the upper left arm, releases air from the suit. The outlet can be adjusted to maintain a desired internal pressure. Thus, when air expands in the suit during ascent, it vents automatically.

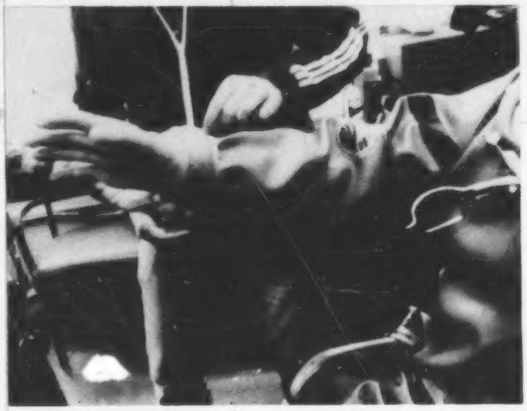
The SuperLite-17B Helmet

The SuperLite-17A/B Commercial Diver's Helmet is constructed of molded fiberglass as shown in Fig. 14.12 and weighs approximately 24 pounds dry.

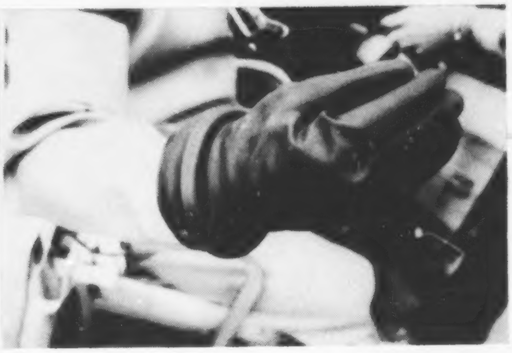
The helmet system consists of two pieces: the neck dam-yoke and the hat. The diver slips on the neck dam with the attached yoke hinging into place. The neck clamp is then slipped onto the hat and locked. The lock system not only seals the neck dam to the hat but also secures the front of the yoke, eliminating any extra steps.

The SuperLite-17B is designed for the requirements set forth by government agencies. The design anticipates future safety requirements by providing a system for prevention of accidental removal, complete head protection, a demand breathing system for gas economy without absorption canisters, antiflooding features, rapid emplacement (even with thick gloves), rapid removal, and a neck dam clamp that breaks a low pressure lock mechanically .

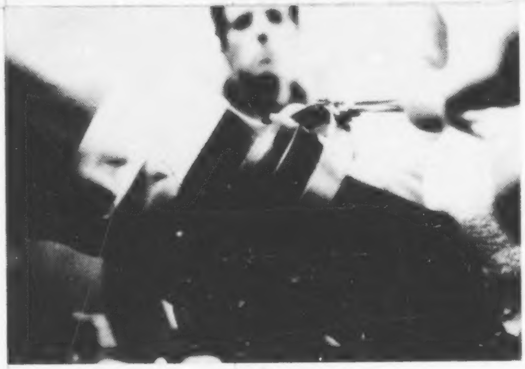
Modifications to the SuperLite-17B include the use of a series exhaust system in which exhaust gases exit from the dive hat through a minimum of two in-line exhaust valves. This valve system eliminates small amounts of water back-flushing into the helmet before a single exhaust can completely close. Secondly, isolation of the second stage diaphragm by a brass cap as shown in Figure 14.13, has been done to protect the diaphragm from potentially dangerous contaminants. Ambient pressure reference is achieved through a tube running from the brass cap to the inside of the helmet



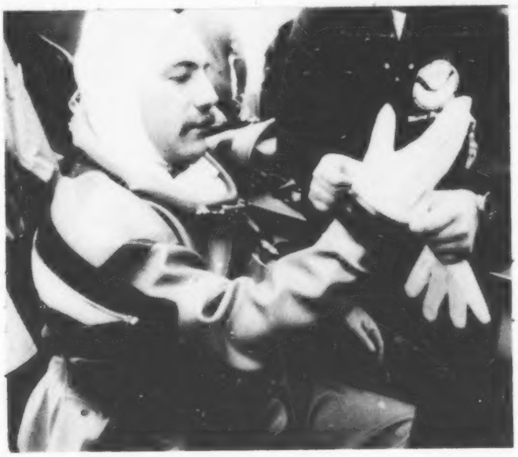
Inner Latex Glove



Outer Heavy Neoprene Glove



Hose Clamp to Secure
Neoprene Glove



Outer Cotton Chafing Glove

Figure 14.11 Multiple Gloving System

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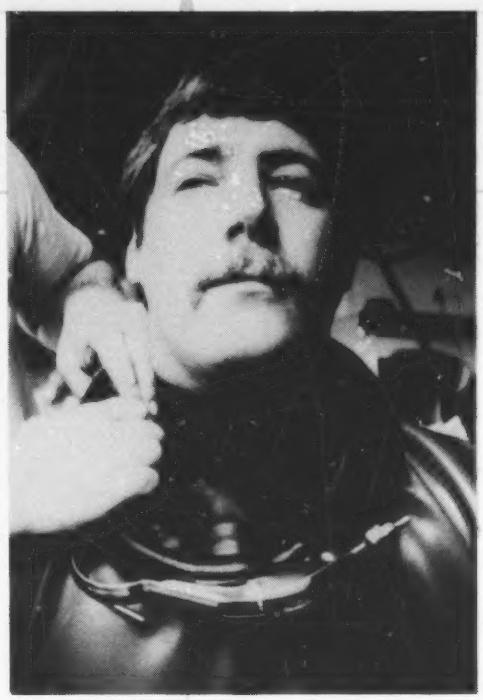

Modified Lower Breach
Ring on Viking Suit for
Superlite - 17B

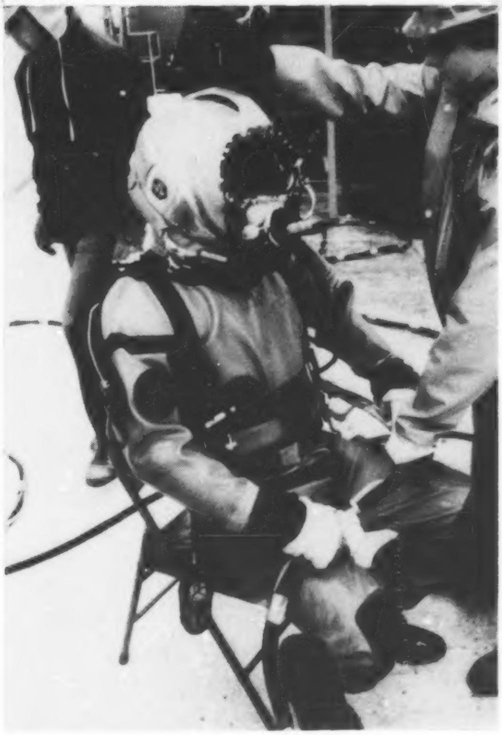

Figure 14.12 Superlite 17-B Helmet w/Modifications

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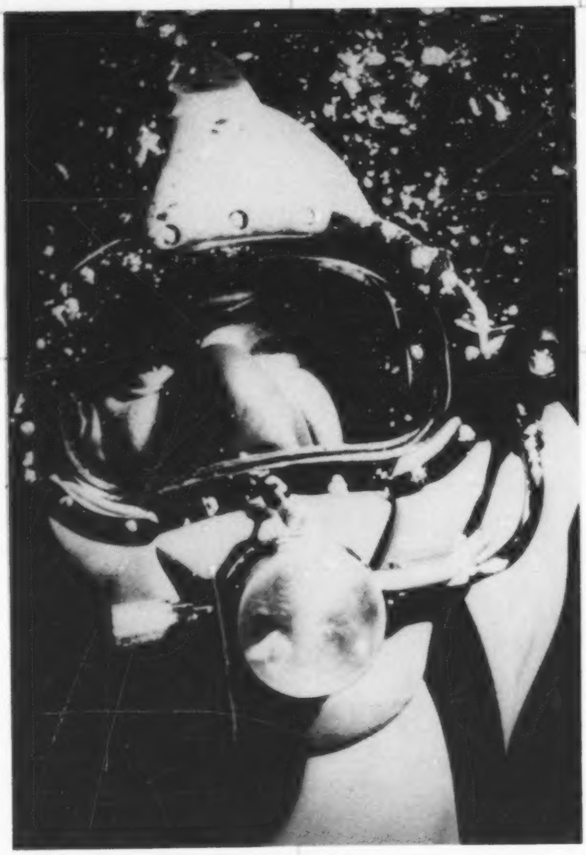

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Figure 14.13 Superlite 17-B Diaphragm Protection Cap

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through existing openings which are located in the helmet shell which were previously used for communications.

By reduction of internal dead air space, the SuperLite-17B requires only 24 pounds of total weight. Placing the weights on the exterior of the hat allows this reduction. This reduction of total weight (30% or more) is very noticeable under water--the hat acts more as part of the diver's head.

Most of the hardware on the forward part of the helmet is interchangeable with the HeliOx-18A/B masks. Because of this interchangeability, spare parts inventories need very little enlargement to handle servicing and maintenance.

The SuperLite-17B was mated with a specially cut Viking heavy duty commercial dry suit as shown in Figure 14.14. The collar of the Viking was arranged so that the bottom "toilet" seat collar was covered by suit material and secured by a drawstring. This created a totally dry seal between the helmet and the suit.

The Helmax SS-20 Model B

The design of the Helmax SS-20 Model B Helmet, shown in Fig. 14.15, by Safety Sea Systems, Inc., is that of a "clam shell" type mask with a hinge-up head protector equipped with locking levers that seal a one-half inch thick stainless steel hood ring between the hull section and the head protector when in the closed and locked position. The mechanical arrangement allows very quick donning and removal of Helmax by the diver in either a standing or sitting position. The hull and the head protector frame are manufactured from stainless steel. The view port is 3/8" thick tuffak (polycarbonate) and is coated with a permanent anti-fog compound. The system is intended for use with an umbilical that will supply the breathable gas and the communication cable.

Helmax is equipped with a demand regulator with an adjustable tensioning device that allows pressure between 80 psi to 180 psi over ambient diver pressure to be adjusted to proper demand sensitivity. Also mounted to the same manifold as the demand regulator is a one-quarter turn free flow valve that is designed for metering a steady flow to the diver. The exhaust valve for the Helmet incorporates a series design utilizing two "mushroom" valves to prevent any contaminated backwatering into the helmet.

The Helmax helmet was mated with a specially modified Viking commercial heavy duty dry suit. The attached hood of the Viking received the Helmax helmet ring which allowed for a totally dry seal to be made.

The Desco Diving Hat

The Desco Diving Hat is of simple, rugged, all-metal construction, that rests on and turns with the diver's head as shown in Figure 14.16. It has approximately neutral buoyancy under water. Its low center of gravity and excellent fore-and-aft balance hold it comfortably and securely on the diver's head in all working positions.

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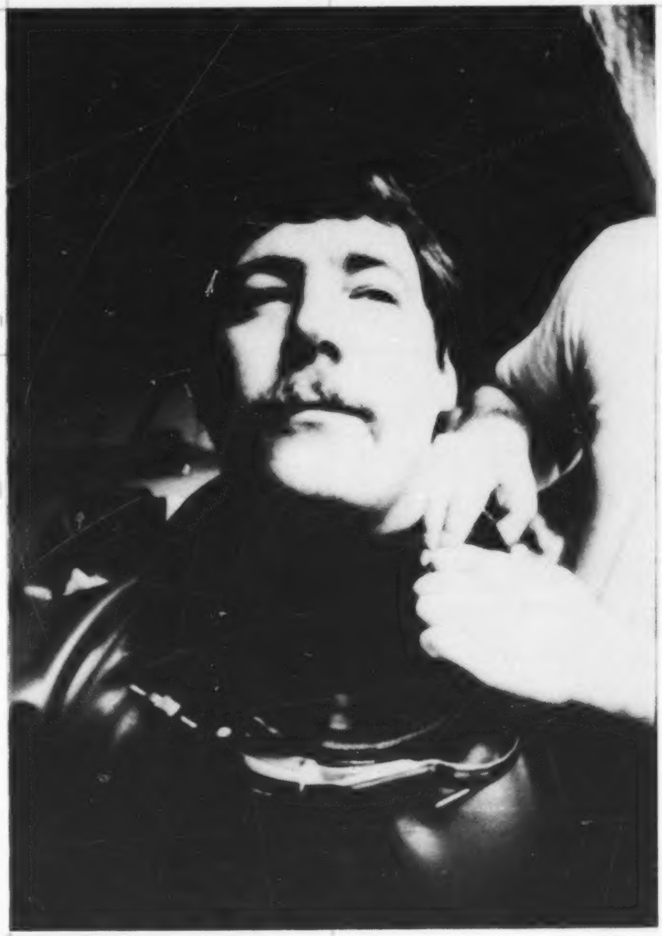

Figure 14.14 Modified Viking Suit for Superlite-17B.

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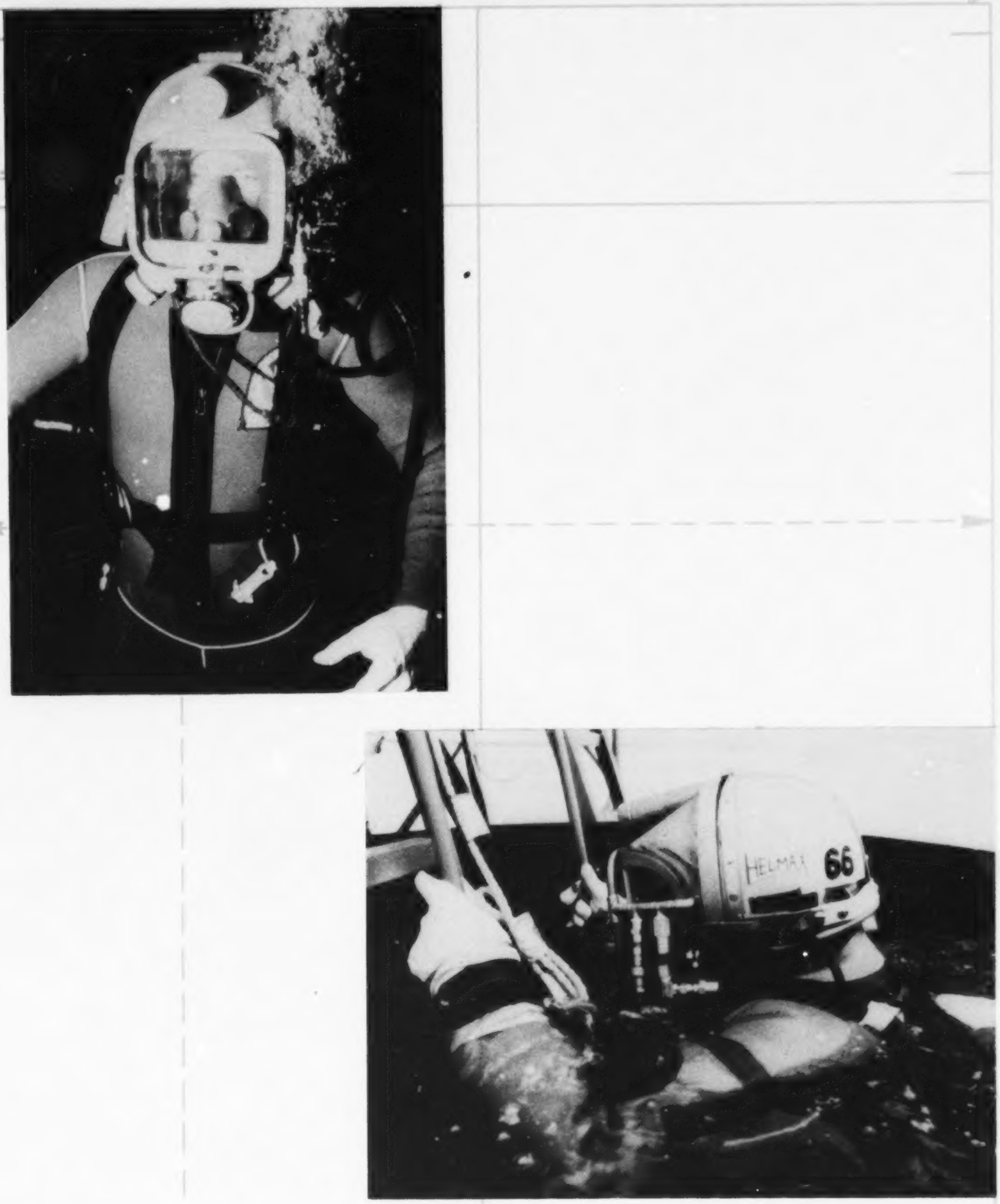

Figure 14.15 Helmax SS-20 Model B Helmet

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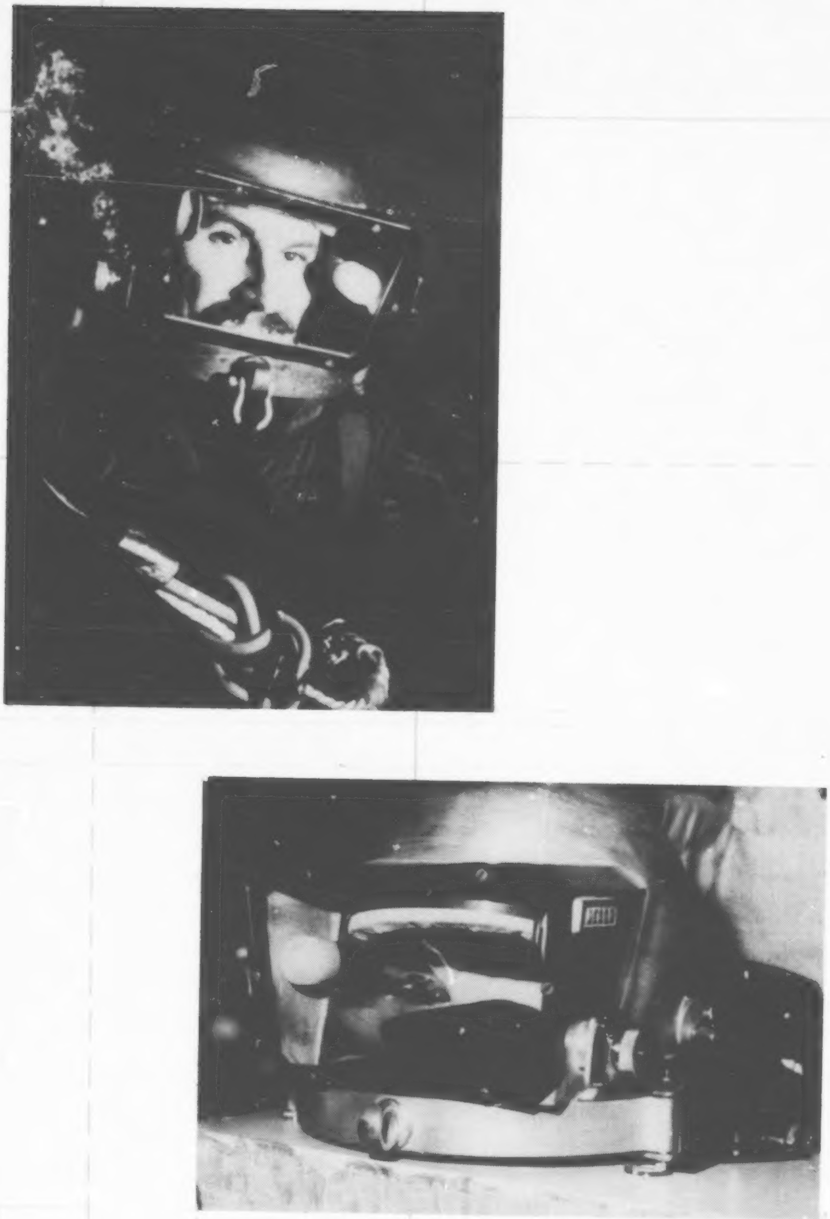

Figure 14.16 Desco Diving Hat w/Modifications

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The neck ring seal is of a new and unique design, providing two independent and complementary waterproof seals. It is designed so that the diver can put the hat on or take it off quickly, in close quarters, without assistance from a tender, and even while wearing heavy gloves.

Unlike the SuperLite-17B, which is a demand air supply system, the Desco Diving Hat is a free air flow system. Air is continually introduced into the helmet to maintain a positive pressure. The only modification made to this system is the addition of the series exhaust which is similar to that mentioned in the SuperLite-17B modifications.

The construction of the neck ring insert permits the hat to be used either with a neck gasket or with an inflatable diving dress having a stretchable rubber collar. In either instance, the dress or neck gasket material can be easily assembled to the neck ring insert without the use of screws and without perforation of the material.

The entire hat may be readily and completely disassembled in the field using only a wrench and screwdriver. Neck gaskets can be changed, or the hat converted to use with a dress or dry suit, without use of tools.

The liner is adjustable to fit various head sizes, and can be removed for cleaning.

A specially modified Viking heavy duty commercial suit was utilized with the Desco Hat. The lower breach ring of the helmet is attached to the Viking suit, providing for a totally dry seal.

SECTION 15

USING SURFACE-SUPPLIED EQUIPMENT

All personnel, divers, and surface tenders should perform a thorough check of equipment. (If a diving operation is staged from a vessel, the ship's captain must be notified that divers are about to enter the water, and clearance should be obtained before the diving operation commences.)

The water should be entered using a ladder as shown in Figure 15.1. Jump entries are discouraged from a height of more than 10 feet above the water.

The air supply system, helmet or mask, and communications should be checked to ensure they are functioning properly. If not, corrections must be made prior to descent.

A descent line should be used at all times in depths greater than 20 feet. Descent rate will depend upon the diver; generally, however, it should not exceed 75 feet per minute.

If descending in a tideway or current, divers should keep their backs to the current so that they will be forced against the descent line. Currents in excess of three knots generally will preclude all diving operations.

When the bottom is reached, the surface tender should be notified and the diver should proceed to the work site. The surface tender also should keep the diver constantly informed of bottom time. The diver should always be notified a few minutes in advance of termination time so there is time to complete the task and prepare for ascent.

Divers and surface tenders should review thoroughly line pull signals. Although voice is the primary means of communication between divers and surface tenders when surface-supplied equipment is used, the line is the backup communication should the voice system fail.

When work is completed, the diver should return to the ascent line and signal the surface tender that he is ready for ascent. The surface tender should pull in excess umbilical line slowly and steadily. The diver should never release the ascent line, but may assist the tender by climbing the line. The surface tender or dive master must inform the diver well in advance of decompression requirements. A diving stage may be required for long decompressions. When decompression is completed, the diver should return on board ship via the ladder or diving stage, with assistance as required from the surface tenders.

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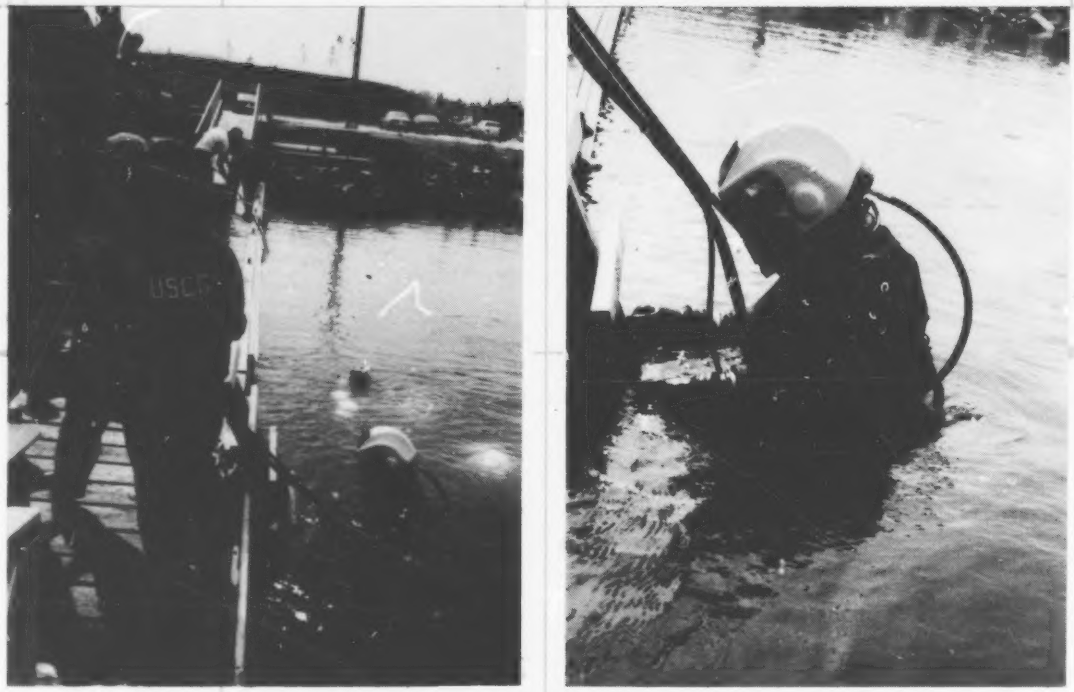

Figure 15.1 Surface-Supplied MK-12 Entry Procedure

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Protecting the Diver

Although the contaminated water problem has been brought sharply into focus during the last decade, the basic nature of the problem has been understood for a long time. Since the inception of diving, part of the development effort has been directed towards solutions to this problem.

Protection Using Surface Supply

The hard-hat diving rig is ideally suited for diving in polluted water. A suit with built-in or attachable gloves covers the diver's complete body. The suit is mated to a breastplate or lower breach ring that is mated to the helmet, and the complete unit is waterproof. The diver's only contact with the environment is ambient pressure through the suit. If the suit has no leaks, and if it is properly cleaned before the diver takes it off, he will be completely protected from contact with the water and anything it contains.

Modern equivalents of the old hard-hat rig do equally well. The main consideration is isolation of the diver. So long as the suit is completely dry, and so long as the mating between suit and hat does not leak, the diver remains unexposed to the contamination. In fact, his tenders are at greater risk than he is because of their exposure to the contaminants while handling the diver and his equipment.

A commercial firm requiring diving in polluted water generally will perform that diving with new equipment to ensure that the diver remain dry and protected. More careful attention is paid to procedure. Equipment repair is more carefully controlled. A firm not willing or able to go to these lengths should contract the job out to another firm that can and will. Some salvage firms have specialized teams who contract out for these jobs.

NOAA found that band masks can be used for diving in biologically polluted water so long as they are used on open circuit instead of demand mode. The effect of using open circuit, by flowing air through the defogger valve while securing the demand valve completely, is to put a slight positive pressure in the mask so that any leakage is from the mask into the water instead of the other way round. When the mask is used in demand mode, the diver's inhalation develops a slight negative pressure inside the mask that causes a slow accumulation of water in the mask. The source of this water is the exhaust check valve in the demand valve and other small leaks throughout the mask. Each inhalation breaks this water into fine droplets which then are inhaled by the diver along with any contamination the water contains. Thus, the contamination problem is compounded by having the diver aspirate the pathogens directly into his lungs.

Band masks are considerably less expensive than hard hats, and they can be used in SCUBA mode without a surface umbilical. Nevertheless, air consumption using a band mask in open circuit is high enough to preclude its being used in SCUBA mode, and so the band mask is limited to surface supply for polluted water use.

There are other limitations to the use of surface-supplied equipment for diving in polluted water. These limitations are especially critical for the research and sport diving groups. The logistics of surface-supplied diving are considerable. Air for the divers can be supplied by one of two means. Either enough large bottles of high pressure air are brought to the dive site to support the required diving, plus a safety factor, plus an emergency supply, or a compressor capable of meeting the same requirements is located at the dive site. It must be noted that in response to a chemical spill, if little volatile organic vapors are present at the dive site, a compressor intake would pump high pressure contaminated air either to the diver or into the cascade system. The utilization of off-site filled cascade bottles is the only acceptable way to supply breathing air to divers at chemical spills. But should the compressor become disabled, there also should be another compressor or a set of emergency high pressure air bottles available. Standard procedure when making surface-supplied dives also calls for the presence of a recompression chamber as shown in Figure 15.2 (NOAA Diving Office, 1981). The presence of a chamber calls for the presence of personnel trained in its use, and for the additional presence of a hyperbarically trained Emergency Medical Technician or a physician, if possible.

The logistics for a safely run surface-supplied diving operation can overwhelm the small organization and are completely out of reach of the individual sport diver.

Required training for diving with surface supplied equipment is not more difficult than that required for SCUBA, but it is different. The U.S. Navy teaches surface-supplied diving before introducing SCUBA when surface-supplied diving is part of the curriculum. This is done to ensure that the required habits for surface-supplied diving are adequately ingrained before the diver familiarizes himself with the independence of SCUBA diving. NOAA teaches SCUBA techniques first because most diving within NOAA is SCUBA. However, selected divers are trained in surface-supplied techniques at a later date. Teaching the SCUBA diver to adjust to the surface-supplied tether has been a continuous problem, as a SCUBA diver does not immediately adjust to the requirements of surface-supplied diving.

If the logistics hurdle can be overcome, the problem of training still must be faced. The research group with adequate funding to handle the logistics could probably also accomplish the training, as the NOAA Diving Office has done. Once again, however, the small group and the sport diver are left out.

There is yet a third problem that must be solved before polluted water can be tackled with surface supplied gear. Surface-supplied equipment is intrinsically more expensive than SCUBA equipment. The state of repair of equipment used for diving in contaminated water is much more critical than that of routinely used equipment. This adds to the cost. Routine operations in polluted water require more frequent replacement of equipment which again increases the cost. As before, the small group and the sport diver have little recourse to this method.

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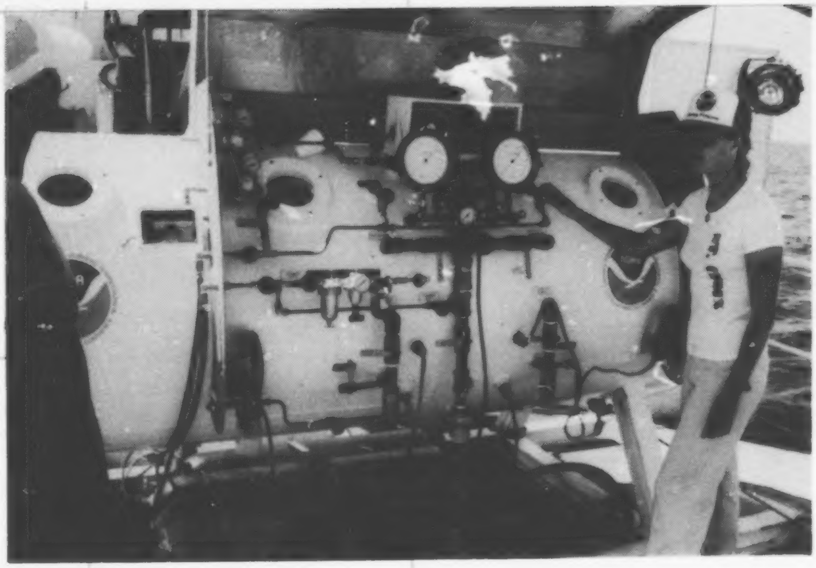

Figure 15.2 48" Diameter, Two Person Recompression Chamber

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Surface-Supplied Diver's Umbilical

The lightweight diving air hose used with the standard mask is a 5/16-inch I.D. oxygen hose manufactured per ZZ-H-461. This hose is designed to withstand a working pressure of 250 psi and a proof pressure of 700 psi held for two minutes. After two years lightweight diving hose shall be hydrostatically tested to 375 psi and held for one minute, with retesting every six months thereafter, until it is retired from service after five years.

Hose used for diving with the standard lightweight mask is supplied in lengths of 50 feet, with a female coupling at each end. Two standard length hoses may be coupled together with a double male fitting if a longer umbilical is required.

In operations utilizing a surface-supplied mask, a leader hose is provided. This leader hose is approximately 30 inches long with a 3/8-inch internal diameter. It leads from the side block assembly to the umbilical attachment at the diver's waist, where it attaches to the umbilical. Either 3/8-inch or 1/2-inch I.D. diver umbilical hose will be used with the mask.

The lifeline serves three purposes: it removes strain from the air hose; it permits tending the diver and assisting him in descent and ascent; and it provides a means for maintaining communications with the diver. The lifeline is made up by the diving unit, using 1-1/4" line of equal strength (300 pound working load minimum). If a surface-supplied mask is to be used, the communications cable should be sized to the lifeline. The lifeline is secured to the diver using either a slip bowline, snap ring, or custom-made harness, and in such a manner as not to interfere with the emergency ditching of the weight belt. The new Navy MK-12 umbilical incorporates the lifeline or "strength" member in the communication line which is made of Kevlar, a material used in bulletproof vests.

A pneumofathometer hose is the final component of the umbilical. It should be adjusted so that the open end will terminate at the diver's chest. This hose gives surface tending personnel the diver's exact depth at all times.

Accessory Equipment for Surface-Supplied Diving

Accessory equipment which are often useful in lightweight diving operations include the following:

- hand leadline for measuring depth.
- descending line to guide the diver to the bottom and for use in passing tools and equipment. This 3-inch line is cable-laid to prevent twisting and to facilitate easy identification by the diver on the bottom. In use, the end of the line may be fastened to a fixed underwater object, or it may be anchored with a weight heavy enough to withstand the force of the current.

- distance line made of 60 feet of 15-thread cable-laid manila. The distance line is attached to the bottom end of the descending line and is used by the diver as a guide for searching as well as a means for relocating the descending line.

- decompression stage, constructed to carry one or two divers, is used both for putting divers into the water and for bringing them to the surface, especially when decompression stops must be made. The stage platform is made in an open grillwork pattern to reduce resistance from the water and may include seats. Guides for the descending line, and several eyebolts for attaching tools, steadying lines or weights, are provided. The frames of the stages are collapsible for easy storage.

- stage line for raising and lowering the decompression stage. It is made up from 3" or 4" manila, nylon or polypropylene rope and marked off at 10-foot intervals to assist in placing the stage at the proper decompression stops. The first "10-foot" mark is placed so that the diver's chest will be maintained at an average depth of 10 feet at his 10' stop. The stage will have to be adjusted slightly depending on surface conditions at the time of each dive.

- diving ladder used when entering the water from the side of a small boat. The ladder is made of galvanized steel, and when in use, it is held at the correct angle by a pair of struts which hold the ladder out from the side of the boat. These struts may be folded for storage.

- cast-iron weights are provided in two sizes: 50 pounds and 100 pounds. Both sizes are used as descending line weights.

- canvas toolbag for carrying tools. The bag may be looped over the diver's arm, or it may be sent down the descending line.

- underwater lights, if conditions permit, may improve the diver's range of vision. A variety of lights are available. A medium pressure light, satisfactory to a depth of 150 feet, uses a normal 100-watt photoflood bulb or any other bulb with a medium base. All underwater lights must be submerged before they are turned on and be turned off before being taken out of the water to prevent breakage due to thermal shock.

- a stopwatch for timing the total dive time, decompression stop time, travel time, etc.

Surface Supply Air Systems

All surface supply air systems that are to be utilized for polluted water diving are thoroughly described in Section 6.2.1 of the U.S. Navy Diving Manual (1973) NAVSEA 0994-LP-001-9010. Figure 15.3 illustrates both a dockside mobile surface supply system and a workboat modified bank for limited space use.

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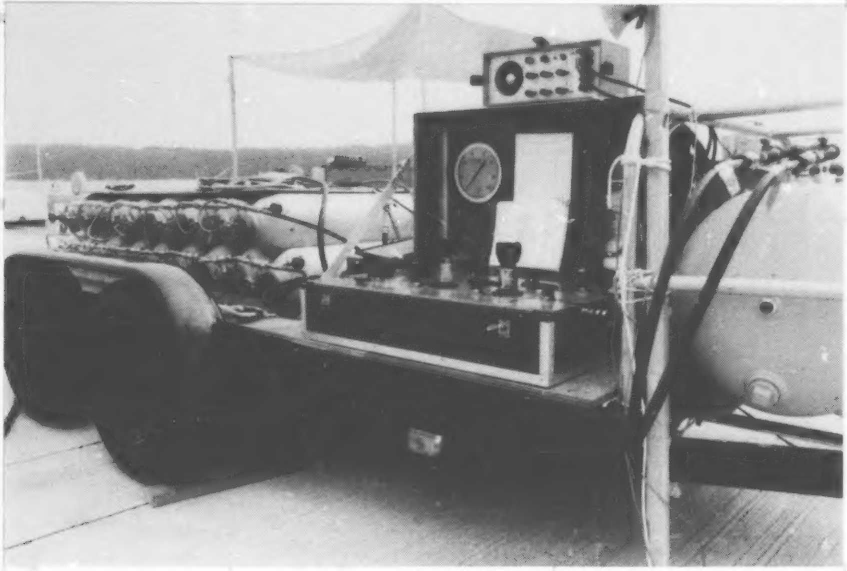
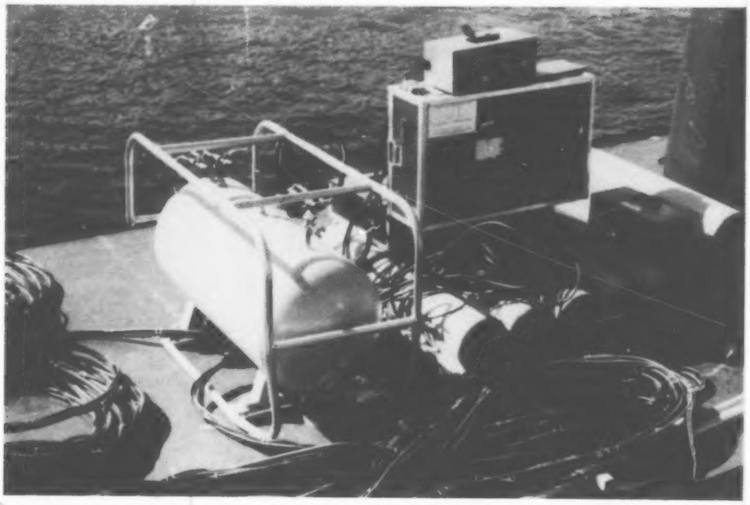


Dockside Trailer Mounted Air Rack
w/Communications Box



Shipboard 01 Deck Mounted Air Rack
w/Communications Box

Figure 15.3 Surface Supply Air Systems

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SECTION 16

HEAT STRESS IN ENCAPSULATED DIVERS

Encapsulated divers who must work in warm contaminated waters are in thermal difficulty. The water need not be hot. People are surprised that lukewarm can be dangerous. Past experiences show surprising results in thermal stress which came from seemingly bland surroundings. The central thread running through these varied experiences is that in all cases there was a restriction of the normal pathways of heat loss from the body, especially the ability to lose heat by evaporation.

Then there are the examples of men who are severely limited by protective clothing. Soldiers in chemical warfare gear can just tolerate warm climatic conditions at rest, but are unable to run, dig, and march; either they collapse from heat stress or they tear off their masks, hoods, and gloves which are completely impermeable. Rocket fuel handlers must wear impermeable coveralls, and it is evident that they cannot work long if it is hot. Various means of cooling have been tried. Similarly, workers in the chemical industry may have to enter a tank to clean or repair it, and their protective clothing and respirators become thermally intolerable if there is no way to cool them underneath the suit. In the nuclear industry, workers in hot zones, hot from radiation, wear complete coveralls for protection, and in many cases they are generously ventilated with clean air through flexible supply and return ducts. Fresh air is vital, both because we must consume oxygen and dump CO_2, and because we have to dissipate metabolic heat.

Losing Heat from the Body

Thermal balance in air environments is well studied. We are accustomed to being able to regulate heat loss in a wide range of temperatures, and for a wide range of activities that vary the internal heat production enormously. When air temperature is well below skin temperature of 33°C (91°F), enough heat flows to the cold air so that we lose internally-generated heat readily. But as soon as either the air is warm or the heat production is high, or both, not enough heat is lost by convective transfer alone. The result is that skin temperature rises, and at 35°C (95°F) sweating begins. As the sweat evaporates, it cools the skin, and thermal balance is restored. Without this physiological response, man would not be able to live in summer, or inhabit the deserts and tropics.

The metabolic heat to be dissipated ranges from around 100 kcal/hr at rest to 300 and 600 kcal/hr during normal physical work. In heavy effort a fit man can sustain levels like 900 or 1,000 kcal/hr. In comfortable air temperatures, surface heat loss by convection is around 50 kcal/hr, and insensible water loss accounts for another 50 or so by evaporation. The cooling from evaporation of sweat is a powerful addition. If a liter of sweat evaporates in an hour, it takes 580 kcal of heat with it. A man who cannot evaporate his sweat is in trouble unless you arrange to chill the air where he works, or supply him with some other form of direct cooling.

Tolerance Limits

When you cannot lose heat as fast as you make it, you store it. The question then is, how much storage is tolerable? The quick answer is: 150 to 200 kcal. So, considering the heat generation rate, it does not take long to accumulate too much if heat loss pathways are sharply restricted.

Thermal tolerance for heat is defined in a number of ways. There is tolerance for heat defined by the person's ability to think, remember, and solve problems. As heat storage accumulates, this sort of cognitive behavior degrades first, then psychomotor performance. As a rule of thumb, these performance limits are reached at about three-fourths the amount of heat storage which defines physiological tolerance. Physiological tolerance for non-compensable heat storage causes, in a resting subject, anxiety, high heart rate, rising rectal temperature, heavy sweating, pallor around the lips and eyes, extreme restlessness, and then loss of consciousness. This used to be called impending heat stroke. It happens when about 150 kcal of heat has been stored and rectal temperature is 39° to 39.5°C (about 103°F). If the man cannot be extracted from the heat exposure, he progresses into clinical heat stroke, a lethal medical emergency. There have been cases of heat stroke in the diving industry, usually in compression chambers, but also in divers in the water. Divers working in the cooling canals and reactor cores of a nuclear generating plant are subjected to water temperatures in excess of 43°C (110°F).

Despite the absence of documented information, it is still possible to speculate on how a diver in complete waterproof encapsulating dress gets too hot in mildly warm water. If he were nude, his skin temperature would be the same as water temperature, and water-skin temperatures from about 28° to 33°C would be comfortable and allow heat dissipation even during hard work. Water in contact with the skin has a high capacity to carry off heat. However, if a suit is placed between the skin and the water, the thermal situation changes remarkably. Because of contaminants in the water, the dive must be totally isolated from it.

Heat transfer from skin to water is hampered by the loss of free convective transfer from skin to moving water because of the physical barrier interposed by the suit. So now the body heat must pass by conduction from skin to suit, by conduction through the suit material, and then to the water. The thicker the suit material, the slower the conduction through it. If underwear is worn, it further slows heat transfer.

The diver moves about and does some work. This requires muscle work, and the temperature in major muscles rises from around 34°C to 38°C. Therefore, the skin overlying thigh and arms and torso gets warmer than its usual 33°C, and soon is warm enough to initiate sweating. It is assumed that the waterproof suit and underwear, however thin, have significantly decoupled the man from the water, and direct heat dissipation is seriously restricted. Now, as sweating fails to cool because there is no way for it to evaporate, the skin is not cooled, and its temperature rises even more. Meanwhile, heat generation continues quickly from work as well as the metabolism needed for just being alive. There is nowhere for the heat to go, so it is stored.

Stored heat can be tolerated only to a certain level--a level which remains to be established for this particular condition of work and thermal restriction. As a guess, it is 200 kcal for the beginning of performance changes.

Stored heat causes the body temperature to rise. Once the surface tissues have risen to near the internal temperature, it takes only 60 kcal to cause a degree of rise in core temperature. If the diver is working at an expected rate of 300 kcal/hr, the time to go from 37° 38°C rectal temperature is only 12 minutes. In 36 minutes he would have reached 40°C. Too hot. Of course there is a buildup time of 10 or 20 minutes before this, so the total time is probably 45 minutes. It is further assumed that the water temperature is not so high that it contributes directly to the thermal burden. This means that the scenario should apply for water temperatures between 25° and 37°C.

If a man had to work in water warmer than 37°C, he would have to store not only his own metabolic heat but that which leaked in through the suit as well. So his time to tolerance would be even shorter.

The great difference between the encapsulated diver and a man doing the same work in warm air is that the diver cannot lose heat by sweating, though sweat he will.

Heat Stress Monitoring

For monitoring the body's recuperative ability to excess heat, one or more of the following techniques should be used as a screening mechanism. In the monitoring of personnel, both divers and surface support tenders, wearing impervious clothing should commence when the ambient temperature is 70°F or above. Frequency of monitoring should increase as the ambient temperature increases or as slow recovery rates are indicated. When temperatures exceed 85°F, workers should be monitored for heat stress after every work period.

1. Heart rate (HR) should be measured by the radial pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 110 beats per minute. If the HR is higher, the next work period should be shortened by 10 minutes (or 33%), while the length of the rest period stays the same. If the pulse rate is 100 beats per minute at the beginning of the next rest period, the following work cycle should be shortened by 33%.

2. Body temperature should be measured orally with a clinical thermometer as early as possible in the resting period. Oral temperature (OT) at the beginning of the rest period should not exceed 99°F. If it does, the next work period should be shortened by 10 minutes (or 33%), while the length of the rest period stays the same. However, if the OT exceeds 99.7°F at the beginning of the next period, the following work cycle should be further shortened by 33%. OT should be measured again at the end of the rest period to make sure that it has dropped below 99°F.

3. Body water loss (BWL) due to sweating should be measured by weighing the worker in the morning and in the evening. The clothing worn should be similar at both weighings; preferably the worker should be nude. The scale should be accurate to plus or minus 1/4 lb. BWL should not exceed 1.5% of the total body weight. If it does, the worker should be instructed to increase his daily intake of fluids by the weight lost. Ideally, body fluids should be maintained at a constant level during the work day. This requires replacement of salt lost in sweat as well.

4. Good hygienic standards must be maintained by frequent change of clothing and daily showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should consult medical personnel immediately .

Real Time Heat Stress Monitoring

Environmental conditions of underwater operations can not only vary with the degree of contamination but also with temperature. Severely cold conditions in the vicinity of 28°F are not unusual for winter or Arctic operations, but the utilization of "hot water" suits have dramatically extended the diver's duration against cold exposure.

However, the water in the cooling pools that surround nuclear reactors and in the canals at nuclear generating facilities that are used for cooling process waters is extremely hot, between 110°F and 120°F.

The use of the SUS suit, described on page 14-2, provides total cooling for the diver in these extremely hot conditions. During tests at the NOAA Diving/Hyperbaric Training Center in Miami, Fla., in December 1983 and February 1984, divers descended into a tank of water that was gradually heated up to 112°F. Each diver's condition was constantly monitored by electrocardiogram and core temperature probes; helmet conditions were monitored by additional temperature probes. At each increase in the water's temperature, the divers were to execute a 20-minute series of exercises.

In the first series of tests, three divers dove without benefit of the SUS suit's cooling system. After performing one 20-minute exercise cycle in 107° water, heart rate increased from 70 to 180 beats per minute, and body core temperature jumped from 98.6° to 102°. All three divers suffered severe heat exhaustion symptoms and had to be helped out of the test tank. Wearing a SUS suit with surface supplied cool water, the divers were able to stay underwater over an hour and complete three 20-minute exercise routines with no evidence of heat stress. What's more, they did so in 112° water, even hotter than the day before, and still emerged "feeling fine."

By this time, the SUS suit and modified versions of two commercially available suits and two helmets had been identified as effective for diving in contaminated waters. The SUS suit will have a working range of 100 degrees: it will warm divers in below freezing water as cold as 30° and water as hot as 130°.

Figures 16.1 and 16.2 show the development and use of a real time heat sensor system incorporated into the diver's medical monitoring harness. The rectal thermal probe gives an accurate reading of body core temperatures of the diver under various work loads and environmental conditions. An additional set of thermal sensors within the helmet monitor heat buildup within the diver's head area, which can be controlled by venting the hat more frequently. All sensors have hard wire telemetry through the surface supported umbilical to a YSI 400 tele-thermometer.

Effects of Heat Stress

If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur ranging from mild (such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement) to fatal. Standard reference books should be consulted for specific treatment.

Heat-related problems are:

- Heat rash: caused by continuous exposure to heat and humid air and aggravated by chafing clothes. Decreases ability to tolerate heat as well as being a nuisance.

- Heat cramps: caused by profuse perspiration with inadequate fluid intake and chemical replacement (especially salts). Signs: muscle spasm and pain in the extremities and abdomen.

- Heat exhaustion: caused by increased stress on various organs to meet increased demands to cool the body. Signs: shallow breathing; pale, cool, moist skin; profuse sweating; dizziness and lassitude.

- Heat stroke: the most severe form of heat stress. Body must be cooled immediately to prevent severe injury and/or death. Signs and symptoms are: red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; coma.

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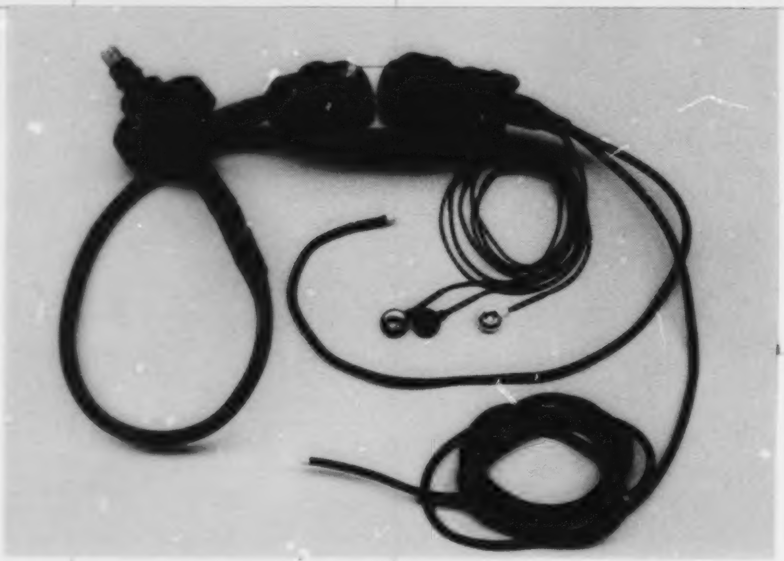

3-EKG Pick-Ups, Helmet and Rectal
Temperature Probes

Figure 16.1 Medical Monitor Harness

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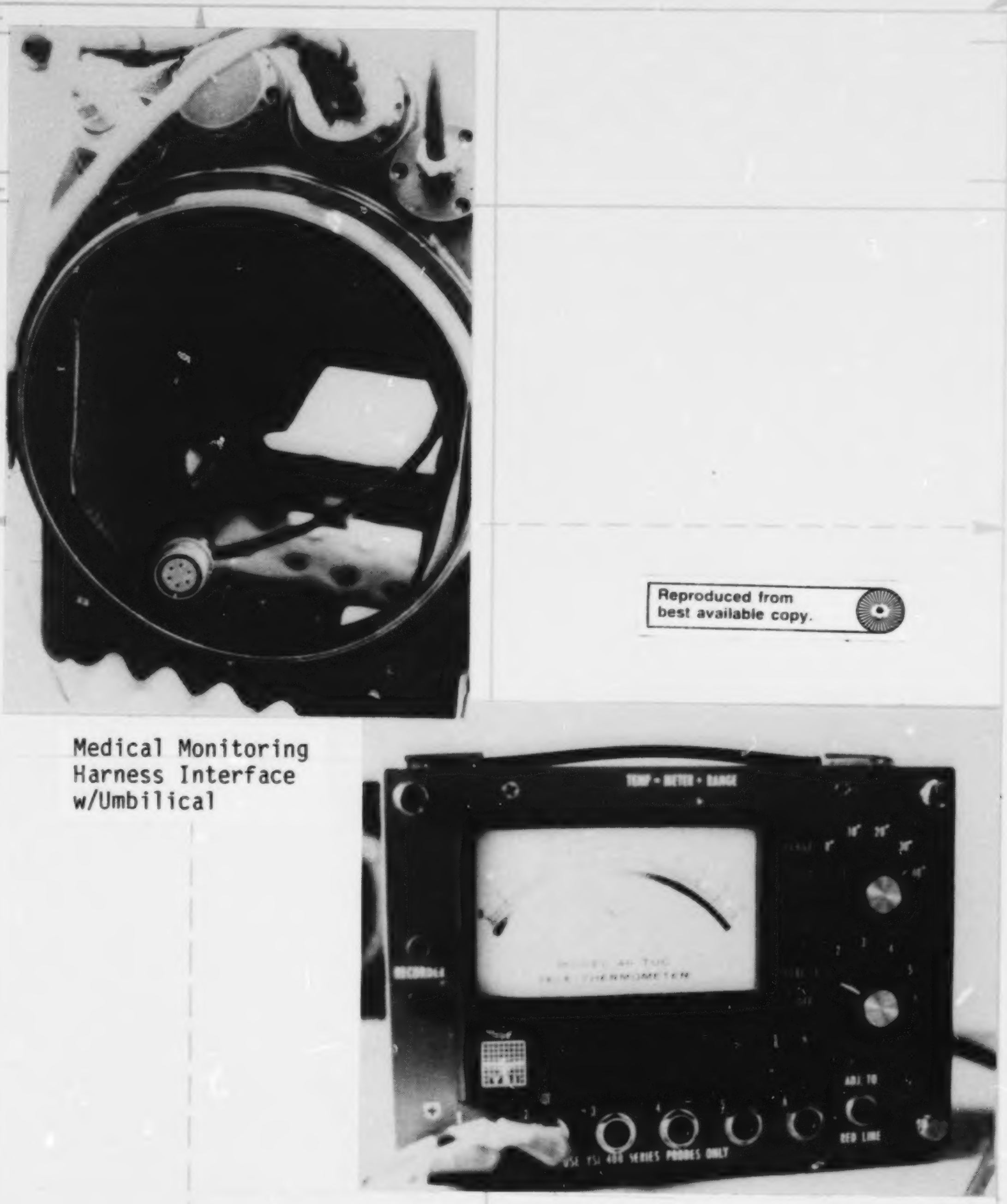

Medical Monitoring
Harness Interface
w/Umbilical

YSI 400 Tele-Thermometer

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Figure 16.2 Surface Body Temperature Monitoring

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SECTION 17

MEDICAL MONITORING

Perspectives on Response Team Exposure Potential

Hazardous materials response personnel, both the diver and surface support personnel, can be exposed to conditions that are typical of normal occupational exposures. Therefore, special attention should be given when developing medical surveillance programs for this type of worker. The team member can be exposed to thousands of toxic chemicals that may or may not be identifiable at the time of response. Even if the substances are identified, potential health effects of exposure to these chemicals or mixtures of the chemicals may not be known. Some other differences between the normal industrial worker and the response team member are as follows:

1. Usually the response team member's exposure to hazardous substances is relatively short in duration and dependent primarily on the length of the cleanup operation.

2. Industrial exposures are controlled by engineering and industrial hygiene practices. However, the response team member's source of protection from exposure to hazardous substances is usually proper work practices and proper utilization of personal protective equipment, e.g., gloves, respirators, coveralls, chemical suits, boots, etc.

3. Generally, industrial exposures evolve from known substances and sources, whereas the response team member may be exposed to substances that are unknown in type, quantity, concentration, etc.

Preplacement/Pre-employment Examinations

Preplacement examinations serve an essential function in health surveillance by providing a historical record of previous exposures, information on the state of health prior to joining the team, and a baseline for comparisons with later health observations. Preplacement examinations are used to ensure that workers are physically able to use personal protective equipment. Employment and medical history, a physical examination, and biological monitoring are elements of the preplacement examination and should be tailored to the specific hazards of the job under consideration.

Hazardous material response personnel may be required to utilize protective respirator equipment. Occupational Health and Safety Standard

29 CFR 1910, Part 134, requires that no employee be assigned to a task that requires the use of a respirator unless it has been determined that the person is physically able to perform under such conditions. The baseline evaluation should determine whether a team member can utilize respiratory equipment. Once a determination has been made as to the physical ability to wear a respirator and perform the work task, a periodic review of the employee's "health status" should be made. Annual evaluations are common practice. It is recommended that a physician with knowledge of pulmonary disease and respiratory protection practices should determine what medical factors are pertinent.

Potential respirator wearers should be examined for any evidence of respiratory impairment such as emphysema, obstructive lung disease, and bronchial asthma. These conditions may justify forbidding a person to wear a respirator that restricts inhalation and exhalation, but would allow the individual the ability to perform adequately in a continuous-flow supplied air device. Other medical conditions that may prevent an employee from wearing a respirator might include: diabetes, epilepsy, use of certain drugs, skin sensitivities, emphysema, chronic pulmonary obstructive disease, and coronary artery disease.

The primary element of any baseline medical evaluation is the completion of a comprehensive medical health history form. In addition, an occupational history questionnaire should be completed so that possible pre-existing exposure to chemicals can be traced. Table 17.1 gives examples of basic parameters that could be considered in an occupational and medical history assessment.

The current general EPA Medical Monitoring Program recommendations are to provide a comprehensive baseline examination for participants in the program. Specific medical monitoring for hazardous materials response personnel is under development and is due for release in the fall of 1983.

Periodic monitoring should include, as a minimum, an interim medical and occupational history review, a screening physical examination, basic blood and urine laboratory tests, and a physician's evaluation. The monitoring examination should be supplemented by procedures and special tests only as warranted by exposure to specific significant hazards or stresses.

Each individual should receive a basic panel of blood counts and chemistries to evaluate blood-forming, kidney, liver, and endocrine/ metabolic function. The following blood tests are considered to be the minimum desirable:

- White blood cell count and differential cell count
- Hemoglobin and/or hematocrit
- Albumin, globulin, and total protein
- Serum glutamic oxalacetic transaminase (SGOT)
- Lactic dehydrogenase (LDH)
- Alkaline phosphatase
- Calcium

TABLE 17.1 OCCUPATIONAL AND MEDICAL HISTORY ASSESSMENT

Occupational History

1. Previous Employers
2. Occupation/Position
3. Industrial Processes
4. Possible Chemical Exposures

Medical History

1. Basic Physical Parameters, e.g., age, sex, height
2. Genetic History Studies (maternal/paternal/siblings), e.g., diabetes, hypertension
3. Personal Health History
    a. Past injuries/illnesses
    b. Allergies
    c. Hypersensitizations
    d. Current medical therapy
4. Exercise Habits
5. Personal Habits
    a. Cigarette smoking
    b. Alcohol
    c. Drug use

- Phosphorus
- Uric acid
- Creatinine
- Urea nitrogen
- Cholesterol
- Glucose

Each response team member should have a routine urinalysis that consists of the following:

- Specific gravity
- pH
- Microscopic examination
- Protein
- Acetone
- Glucose

X-Ray--

A baseline chest X-ray should be a standard 14 x 17-inch P-A (posterior-anterior) exposure. The lateral view is not necessary for routine screening purposes. The X-ray may be obtained from the examining physician, a local radiologist, or a local hospital. The film should be read or reviewed by a board-certified radiologist or other competent medical specialist. Subsequent periodic chest X-rays should be performed only when clinically indicated and not as a routine measure.

Electrocardiogram--

An electrocardiogram should be included in the baseline examination. Ordinarily it should be of the standard 12-lead resting type and interpreted by an internist or cardiologist. Subsequent periodic electrocardiograms should be obtained only when recommended by the examining physician, and not as a routine measure. Figure 17.1 shows a three lead EKG pickup and a Lifepak 4 heart monitor for real time tracking of work stress.

Pulmonary function--

Pulmonary function testing is desirable as a part of the baseline examination. It may be indicated periodically for employees at respiratory system risk, such as those with significant exposure to toxic dusts and irritants. As a minimum, it should consist of simple tests of lung ventilation: forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC).

Workers who are significantly exposed to certain designated materials may require additional special procedures in addition to the basic panel of tests. The physician should determine who is in need of special tests after reviewing the history forms and after consulting with supervisors and/or medical monitoring coordinators and health and safety designees. Provision should be made for repeating tests when necessary. Consultative assistance is available from the EPA Occupational Health and Safety Staff regarding special tests.

Ambient air monitoring--

While not a true medical monitoring function, it is desirable to monitor the helmet atmosphere of the diver for contamination. Figure 17.2 shows the use of a battery operated air sampling pump known as a Poly Meter which is worn under the divers dress. This unit pulls a measured air flow through a specific chemical detector tube which will measure the concentration by discoloration. The diver and tenders are able to measure any contamination just by visual observation. Based upon prior knowledge of what contamination is present, the appropriate detector tube can be selected.

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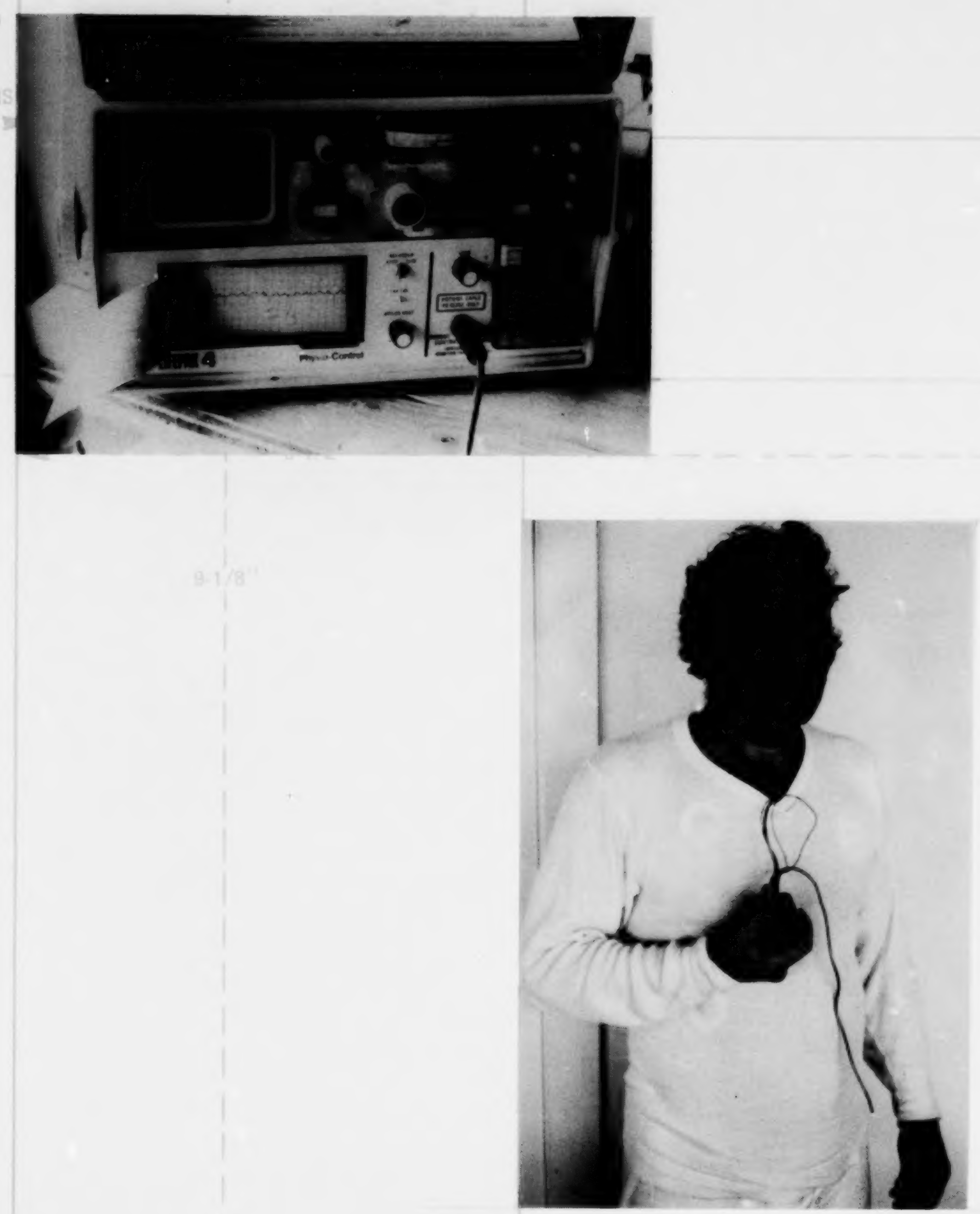

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Figure 17.1 Three Lead EKG Pickup and Lifepak 4 Heart Monitor

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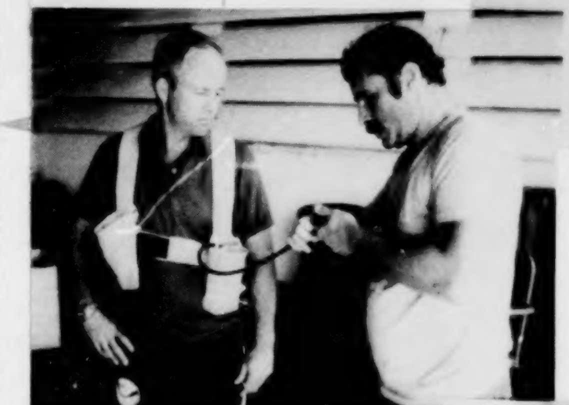
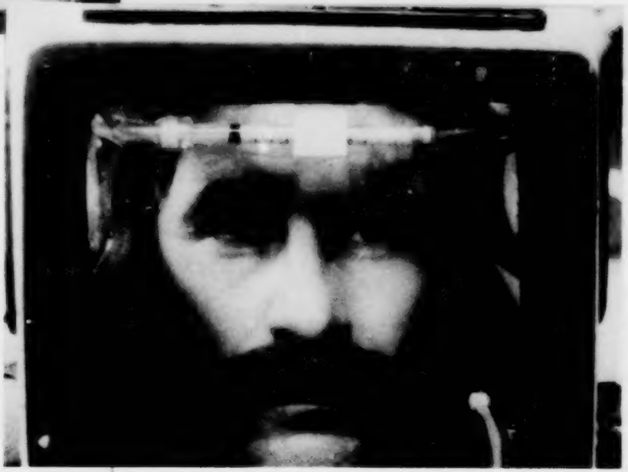
Specific Chemical
Detector Tube



Poly Meter Air
Sampling Pump



Position of Helmet Mounted
Detector Tube

Figure 17.2 Ambient Helmet Air Monitoring

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SECTION 18

PERSONNEL PROTECTION FOR SURFACE SUPPORT OPERATIONS

A major area of consideration that has not been addressed previously is the protection of surface tenders and support personnel. Previous commercial operations have shown that the recovery of sunken chemical drums and containers onto work barges will lead to some degree of contamination of the ship's deck and surrounding equipment. Umbilical and line tenders handling the divers' support hoses will come into intimate contact with the contaminated water. Appropriate levels of personnel protection must be defined for these special situations. The limited deck area will not allow for large "clean areas" for personnel decontamination and changing of self-contained breathing apparatus (SCBA) air tanks. Depending on the level of hazardous material toxicity, this could dictate the need for airline-supplied respirators for surface support personnel functioning in the high-contamination areas. Also, appropriate considerations and procedures need to be developed for decontamination of surface support personnel. "Clean" locations must be developed for suiting up divers, and procedures for moving divers and their gear back to decontamination stations. Specific procedures need to be developed for umbilical, helmet, and diver dress decontamination operations.

Evaluating the hazards associated with toxic chemical spill incidents involves various degrees of complexities. The release of a single known chemical compound does not represent as difficult a problem to assess as an incident involving multiple compounds. Likewise, it becomes progressively more difficult to determine hazardous effects as the number of compounds increase.

The most important first step though is to insure the safety of all personnel involved in the spill incident.

Routes of Exposure

Only three natural pathways of chemical exposure to the body exist:

1. Through body contact (skin, including eyes and hair),
2. inhalation, and
3. by ingestion.

The primary function of the skin is to act as a barrier against entry of foreign materials into the body. However, this protective barrier can be overcome, permitting chemical toxins to enter. The protective nature of the skin can be greatly diminished by lacerations, abrasions, and moisture. Also, many organic solvents can greatly increase the permeability of the skin to materials that would otherwise not pass through it. Another factor is that the skin provides a large area for surface contact of the toxin.

Inhalation is the most rapid exposure route. Toxins are introduced to respiratory tissue and the boodstream immediately. Once admitted to the blood through the lungs, these toxic chemicals are quickly transported throughout the body providing contact with all organs.

Health hazards to personnel from ingestion of materials are of minimal concern relative to skin and respiratory hazards. The number of substances that can be ingested are limited; i.e., it is difficult to swallow vapors and gases. Also, contact with ingestible materials is limited in that they only get to the mouth through hard contact. Even when ingested, toxicity by mouth is of a lower order due to subjection to acidic, alkaline, enzymatic conditions of the gastrointestinal tract. However, these same conditions may enhance the toxic nature of a compound. It should also be noted that gum and tobacco chewers can absorb appreciable amounts of gaseous substances during an eight-hour work shift.

The establishment and execution of personnel protection programs when responding to hazardous chemical spills or releases find their basis in the letters "IDLH".

The definition of IDLH provided in 30 CFR 11.3(t) is as follows:

> "Immediately dangerous to life or health" means conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials, which are likely to have adverse cumulative or delayed effects on health."

The purpose of establishing an IDLH exposure concentration is to ensure that the worker can escape without injury or irreversible health effects from an IDLH concentration in the event of failure of the respiratory protective equipment. The IDLH is considered a maximum concentration above which only highly reliable breathing apparatus providing maximum worker protection is permitted. Since IDLH values are conservatively set, any approved respirator may be used up to its maximum use concentration below the IDLH.

Levels of Protection

It is important that personnel protective equipment and safety requirements be appropriate to protect against the potential or known hazards at an incident. Protective equipment should be selected based on the types(s), concentrations(s), possibilities, and routes of personnel exposure from substances at a site. In situations where the type of materials and possibilities of contact are unknown or the hazards are not clearly identifiable, a more subjective determination must be made of the personnel protective equipment required for initial safety. Level B protection is the minimum level recommended on initial entries until the hazards have been further identified and defined through monitoring, sampling, and other reliable methods for analysis; and personnel protection equipment corresponding with those findings can be utilized.

The appropriate level of protection shall be determined prior to the initial entry on-site based on best available information. Subsequent information may suggest changes in the original level selected. Recommended levels of protection are:

1. Level A

   Level A protection should be worn when the highest available level of respiratory, skin, and eye contact protection is needed. While Level A provides the maximum available protection, it does not protect against all possible airborne or splash hazards. For example, suit material may be rapidly permeable to certain chemicals in high air concentrations or heavy splashes. (See Figure 18.1)

2. Level B

   Level B protection should be selected when the highest level of respiratory protection is needed, but cutaneous or percutaneous exposure to the small unprotectec areas of the body (i.e. neck and back of head) is unlikely, or where concentrations are known within acceptable exposure standards. (See Figure 18.1)

3. Level C

   Level C protection should be selected when the type(s) and concentration(s) of respirable material is known, or reasonably assumed to be not greater than the protection factors associated with air-purifying respirators; and exposure to the few unprotected areas of the body (i.e. neck and back of head) is unlikely to cause harm. Continuous monitoring of site and/or individuals should be established. (See Figure 18.1)

4. Level D

   Level D is the basic work uniform and should be worn for all site operations. Level D protection should only be selected when sites are positively identified as having no toxic hazards. (See Figure 18.1)

Respiratory Hazards and Protection:

The lungs do not have defenses which are 100% effective against toxic gases, vapors or particulates. Such hazards may impair or destroy portions of the respiratory tract or they may be absorbed directly into the bloodstream. Those hazards in the blood may eventually affect the function of other organs and tissues. The lungs must be protected from toxic hazards. This can be accomplished by avoiding or minimizing exposure. Engineering controls such as ventilation will help decrease exposure. However, when such controls are not practical or feasible, protection can be afforded by the use of respirators.

There are respirators which filter gases, vapors, and particulates in the ambient atmosphere. When concentrations are too high, respirators are available which will supply a clean source of breathable air to the wearer.

Oxygen Deficiency:

The body requires oxygen to maintain the various ongoing process. If the oxygen concentration decreases, the body will react by exhibiting various symptoms. Dealth will occur when the concentration reaches only 6%. The effects of oxygen deficiency are listed on the following table.

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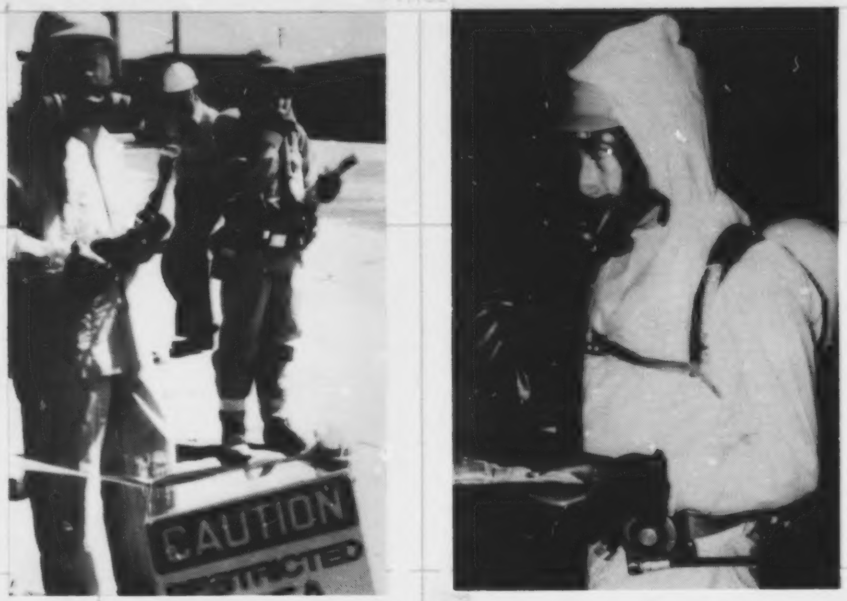
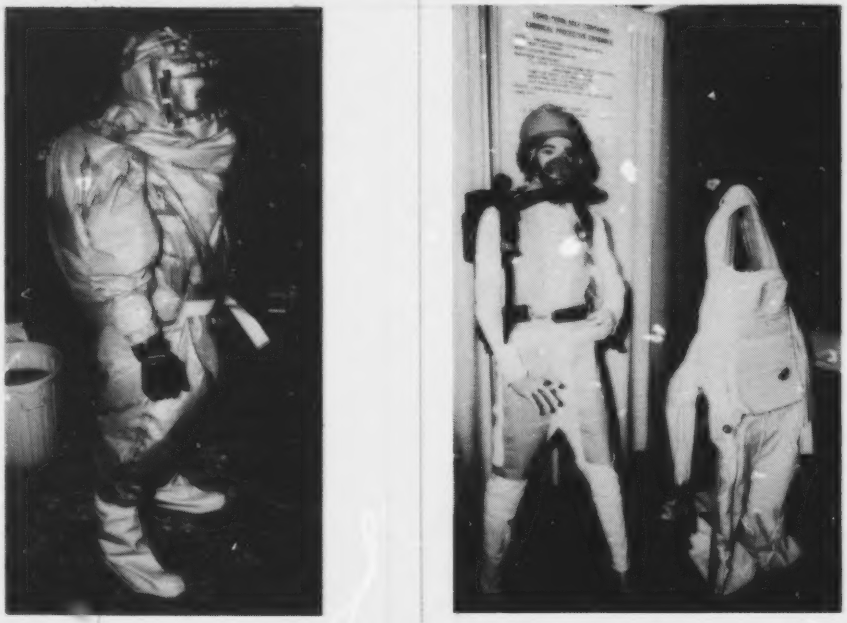


Level "C"

Level "B"



Level "A"

Experimental 2 1/2 Hour Level "A"

Figure 18.1 Levels of Personnel Protection

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O_2 Vol % At Sea Level	Physiological Effect
16-12	Increased breathing volume, accelerated heartbeat, impaired attention and thinking, impaired coordination.
14-10	Very faulty judgment, very poor muscular coordination, muscular exertion causes rapid fatigue that may cause permanent heart damage, intermittent respiration.
10-6	Nausea, vomiting, inability to perform vigorous movement, or loss of all movement, unconsciousness, followed by death.
Less than 6	Spasmotic breathing, convulsive movements, death in minutes.

Aerosols

Aerosol is a term used to describe particulates in air without regard to their origin. Particulates are collected on the walls of the nasal cavities and conducting tubes. Particulates ranging in size from 5 to 30 microns are deposited in the nasal and pharnygeal passages. The trachea and smaller conducting tubes collect particulates 1-5 microns in size. Any particulates which travel into the conducting tubes are carried by force of inhalation. For particulates to reach the alveolar spaces they must diffuse from the smallest conducting tubes into the alveolar spaces. Only particulates less than .5 microns in diameter diffuse into the alveoli. Larger particles do reach the alveolar spaces due to gravity and settling. The smallest particulates may never be deposited in the alveoli and so may diffuse back into the conducting tubes to be exhaled.

Gaseous Contaminants

Gases and vapors are filtered to some degree by the respiratory tract. If soluble, gases and vapors will be absorbed into the walls of the passages to the alveolar spaces. Not all will be absorbed and so they will finally diffuse into the alveolar spaces. Here, the gases or vapors can be directly absorbed into the bloodstream.

Respiratory Protective Devices

Respiratory apparatus can be divided into two general types: Air Purifying and Atmosphere Supplying. These two categories can be further divided into groups based on their construction and operation.

All respirators are composed of two main components: the facepiece and the device which supplies or purifies air. The facepiece comes in three configurations which is directly related to the amount of protection afforded by the respirator:

1) Quarter Mask (Type B - Half Mask) fits from nose to top of chin and utlizes two-or four-point suspension.

2) Half Mask (Type A - Half Mask) fits under chin and over the nose. To be approved it must have four-point suspension.

3) Full Facepiece covers all of the face from under the chin to the forehead.

The full facepiece provides the best protection because it is more easily fitted on the face than either the half or quarter mask.

Equipment Classification - General Considerations

Air Purifying Respirators--

The use of air purifying respirators is predicted on several factors. The atmosphere that the respirator is to be used in must have at least 19.5% oxygen. The concentration of the contaminant must be at IDLH levels.

Mechanical filters are used for particulate hazards and chemical sorbents are used for gases and vapor hazards. Respirators are approved for use up to predesignated concentrations. The respirator is also limited by its length of service which is based on the contaminant concentration.

Another important requirement is that the contaminant being filtered have warning properties which will alert the user to the exhaustion of service capacity of the respirator.

Atmosphere Supplying Respirators--

There are four types of respirators which supply breathing air to the user. Atmosphere-supplying respirators provide from five minutes to several hours of breathing air. The first type and the oldest is the oxygen generating respirator. This type of respirator has a canister which converts carbon dioxide to oxygen. Oxygen generating respirators have been used in the military and for escape purposes in mines.

The hose mask is another type of atmosphere-supplying respirator. It utilizes a remote source of a clean atmosphere. The clean air is drawn through the hose by the user or by a blower. The airline respirator is similar to the hose mask except that the source of air is compressed.

Self-contained breathing apparatus (SCBA) uses a cylinder to hold compressed air or oxygen and allows the wearer to carry it with him/her without the confinement of a hose or airline. SCBA's and airline respirators operate in one of several modes, continuous demand or pressure demand.

The amount of protection an atmosphere-supplying respirator gives is based on two factors: the type of facepiece and its mode of operation. As was indicated earlier, the full face mask provides the best protection. Of the three modes of operation, continuous, demand, and pressure demand, the pressure demand mode provides the best protection. Airline respirators may use any one of the three operational modes. SCBA's will operate in either demand or pressure demand. Hose masks are considered to be demand operated.

An escape SCBA must have at least 5 minutes of breathing air available. From 5-15 minutes of air supplies are found with escape devices. This escape supply is stored in a small cylinder or coiled stainless steel tubes.

Escape devices are not to be used for entry into hazardous atmospheres under any circumstances.

To beat the major limiting factor of SCBA's, air supply, combination airline and SCBA's have been manufactured. The SCBA may be used to enter and retreat from the site if there is enough air (greater than 15 minutes). The airline is used to supply air while the person is working on-site.

This outline is not complete by any means.

Protective Clothing

The hazardous properties of chemical substances necessitates the use of protective clothing. The degree of protection required is dictated by the predominant physical, chemical, or toxic property of the material. For example, protection required for a corrosive compound is different from that of a compound which releases a highly toxic vapor. The type of activity, such as work or observation around the substance, must also be considered when assigning protective clothing. As with the selection of proper respiratory protective apparatus, a thorough assessment of the encountered hazards must be completed before any decision making.

Once the specific hazard has been identified, the appropriate clothing can be selected. Several factors must be considered in the selection of clothing. The most important is the safety of the individual. The level of protection assigned must match the hazard confronted. It is also very important that the individual be well-trained in the use of procedures for site activities. Other factors include cost, availability, compatibility with other equipment, suitability, and most important, performance.

Performance Requirements

The primary safeguard of any protective clothing is the material from which it was manufactured. In selecting a suitable piece of protective clothing, the following characteristics of the protective material should be considered: strength, flexibility, thermal limits, cleanability, lifetime, and chemical resistance.

The strength of a material is based on four specific requirements. It must be resistant to tears, punctures, and abrasions, and it must possess suitable tensile strength.

For ease of movement and to facilitate work activity in protection clothing, the material should be flexible enough to allow such activity. Dexterity is especially important in materials used in the manufacture of gloves.

The ability of clothing to maintain its protective capacity in temperature extremes is advantageous. Also to be considered is the allowance of mobility in cold temperatures and transfer of heat to the wearer in hot climates.

Decontamination can be difficult and expensive if the protective clothing is not launderable. Some materials are nearly impossible to clean sufficiently under any circumstances. Because of these problems, much protective clothing is being considered disposable.

Some types of clothing are more durable than others when subjected to severe conditions over time. The ability to resist aging and the initial cost of the garment should be considered before procurement. Here again is an advantage of disposables.

The final and most important consideration is the chemical resistance of the protective material. When clothing comes in contact with a hazardous liquid or vapor, it must maintain its structural integrity and protective qualities.

Chemical Resistance

Resisting chemical attack by a protective material is not a simple task. The material must be able to avoid degradation, penetration, and permeation by the insult chemical. Any or all of these actions may result upon contact, especially when prolonged.

A protective material may or may not be affected by a chemical agent. If the material is inert to that substance, then it will not be degraded. However, this does not preclude penetration or permeation of the material by the agent. Any level of degradation of the protective material may occur if it is reactive with the chemical agent. Damage to the material may be as severe as complete deterioration of the protective material. Contact with the agent and subsequent permeation may result in the swelling or shrinking of the material or a change in its structure and chemical makeup. Changes such as these may serve to enhance or restrict permeation by the chemical agent.

The penetration by a chemical through a protective material is the result of design and construction imperfections. Penetration is not affected by the actual protective material. Stitched seams, button holes, porous fabric and zippers will allow a hazard to penetrate the protective garment. A protective suit with self-sealing zippers and lapped seams made of nonporous elastomeric material will prevent penetration because of its design and construction. However, as soon as that suit is ripped or punctured, its ability to avoid penetration is lost. Again the suit with the finest design and manufacture may still be permeable and degradable while maintaining impenetrability.

The ability of a protective material to resist permeation is a characteristic of that material. When a chemical agent comes in contact with the protective material, a concentration gradient is established. The concentration of the agent opposing the outside wall of the material is high, and the concentration inside the material is low (or zero). Because the tendency is to establish equilibrium, diffusion and other molecular forces "drive" the agent into the material. When the agent passes completely through the material, it will condense on the inside wall and/or diffuse into the atmosphere opposing this inside wall. The process of permeation will continue as long as te concentration gradient remains greater in the outside atmosphere. The amount of time required for this sorption process to begin is the initial breakthrough point.

The permeation rate is based upon several factors. These include the concentration of the attack chemical and the thickness of the protective material. The rate is inversely proportional to the thickness of the material while the concentration is directly proportional to the permeation rate.

The amount or degree of permeation is related to the exposure conditions which include temperature and contact time. The contact time will ultimately dictate how much of the chemical will successfully permeate the protective material. The use of protective clothing warrants a conscious effort to avoid prolonged exposure or contact with any hazardous chemical.

It is important to be cognizant of the fact that no material will resist permeating by all agents. Some degree of permeation can be expected in most cases. The various types of protective materials usually possess the ability to protect only against certain classes of chemicals. The other classes of compounds may readily permeate the material.

Once a liquid or vapor is sorbed by the material, there is a need for laundering. The ability to be completely decontaminated is an advantageous characteristic of protective material. Most materials, no matter how resistant to strength loss, will allow permeation. With many of these materials it is impossible to remove al contamination completely. Materials such as butyl rubber and viton, which will desorb most contamination upon cleaning, are available but also expensive. This is where the use of disposable clothing may be advantageous.

The Naval Surface Weapons Center, Dahlgren, VA is currently conducting extensive chemical permeation tests on the various materials found in diving suits, helmets and exhaust assemblies. Once this data has been released to the public it will be incorporated into this section under the final protocol.

Chemical Resistance Charts

In choosing protective materials based on a selected hazard, various tables are available which indicate relative effectiveness. It is important to recognize that such tables reflect only the material's ability to resist degradation by the agent. This is not the same as resistance to permeation. A material may be physically unaffected by a substance, but may still be very permeable to that agent. This is not to say that such charts are not useful. They can be so long as the seriousness of the hazard is properly considered. If the hazard is extremely toxic, then any activity involving that agent should be reevaluated. The potential risk involved must be weighed against the potential gain.

Table 18.1 provides an illustration of available data usually presented by the manufacturer. (This information is general and indicates effectiveness by generic classes of chemical compounds). Upon studying this table, it is apparent that the protective capabilities of these materials are variable.

1. Tyvek - a DuPont product described as a spun bonded olefin which is made of nonwoven polyethylene fibers. In this form, Tyvek has reasonable tear, puncture and abrasion resistance and is excellent in holding out particles. Another desirbale quality of this material is its resistance to static build-up. Once laundered, it loses that property. Tyvek is inexpensive and suitable as a disposable garment. Its melting point is 270°F.

2. Nomex - This is another DuPont product. Nomex is composed of an aromatic polyamide fiber. It is noncombustible and has flame-resistance up to 220°C, thus providing good thermal protection. It is also very durable and acid-resistant. Nomex is easily laundered.

3. Polyethylene - This is an inert yet permeable material. It is sometimes used as a coating or Tyvek garment which gives them resistance to acids, bases, and salts. Polyethylene will absorb organic solvents.

4. Polyvinyl Chloride (PVC) - This material is used to manufacture many types of protective clothing. It is resistant to acids but will also allow permeation. Upon decontamination, PVC will retain traces of the contamination. PVC has been coated on Nomex to develop a strong protective material. Fully encapsulating suits such as the Wheeler Acid King and the MSA Rocket Fuel Handlers suits are examples of such a combination. These suits cost in the neighborhood of $600.00.

5. Neoprene - This synthetic elastomer provides very good protection aganist many chemicals. Keep in mind that a material which will not degrade may still be permeated. Neoprene provides better protection than PVC but as with PVC, it will retain contaminants upon decontamination. Many respirator facepieces and breathing hoses are also made of neoprene.

6. Chlorinated Polyethylene (CPE) or Chloropel - This material is manufactured by ILC Dover and used in the manufacture of splash suits and fully encapsultating suits. The U.S. Army is currently testing prototype suits as protection against nerve agents and the U.S. Coast Guard is also conducting tests with suits made of CPE. The manufacturer supplies chemical resistance information but no data on permeability. it is considered to be a good all-around protective material. Four hundred dollars will be sufficient to buy a suit made of CPE.

7. Butyl Rubber - This material is especially resistant to permeation by gases. It is used in the manufacture of boots, gloves, splashsuits, aprons, and fully encapsulating suits. The Army has been using butyl rubber garments against toxicological agents for many years. Butyl Rubber is resistant to many compounds except halogenated hydrocarbons and petroleum compounds, which is a common deficiency of most protective materials. One advantage Butyl Rubber does have is its ability to release all contamination upon laundering.

Table 18.1. CLOTHING MATERIALS CHEMICAL PROTECTION BY GENERIC CLASS

Generic Class	Butyl Rubber	Poly Vinyl Chloride	Neoprene	Natural Rubber
Alcohols	E	E	E	E
Aldehydes	E-G	G-F	E-G	E-F
Amines	E-F	G-F	E-G	G-F
Esters	G-F	P	G	F-P
Ethers	G-F	G	E-G	G-F
Fuels	F-P	G-P	E-G	F-P
Halogenated Hydrocarbons	G-P	G-P	G-F	F-P
Hydrocarbons	F-P	F	G-F	F-P
Inorganic Acids	G-F	E	E-G	F-P
Inorganic Bases and Salts	E	E	E	E
Ketones	E	P	G-F	E-F
Natural Fats and Oils	G-F	G	E-G	G-F
Organic Acids	E	E	E	E

E - Excellent
G - Good
F - Fair
P - Poor

Source: Survey of Personnel Protective Clothing and Respiratory Apparatas. September 1974, DOT, USCG, Office of Research and Development.

Chem-Pro of East Wind, Inc. manufactures fully encapsulating suits and other Butyl Rubber garments. Their fully encapsulating suit is used a great deal by EPA and its contractors. A Butyl Rubber suit is available for nearly $1,000.00.

8. Viton - This is a DuPont fluoroelastomer which has recently been employed in a fully encapsulating suit. The suit is manufactured by Chem-Pro of East Wind, Inc. Viton has been tested for permeability and it has been shown that its overall protective capabilities, especially with liquids, surpasses that of butyl rubber and neoprene. There are chemicals which Viton is not as effective as other materials such as the ketones and aldehydes. Viton also has the ability to extricate all contaminants upon thorough cleaning which is an advantage over other materials which do not. A fully encapsulating Viton suit costs about $3,000.00.

9. Others:

   a) Natural rubber - used in the manufacture of boots and gloves. It resists degradation by alcohols and caustics.

   b) Nitrile - This material is being used in protective boots and gloves because of its resistance to petroleum products.

   c) Poly Vinyl Alcohol (PVA) - This is an excellent protective material for use against aromatic and chlorinated hydrocarbons. The major problem with PVA is the fact that it is soluble in water.

It is evident that there are protective materials available for specific chemical hazards. Yet, there is really no one material good for all types of hazards; thus, selection can be difficult. Because protection can be limited by the protective material employed in the suit or gloves, several layers of protection should bq considered. Disposable boots and gloves and PVC rainsuits serve such a purpose. They can be used to provide an extra layer of protection and then discarded. This also lessens the amount of decontamination required for the inside layer of garments.

Types of Protective Clothing

As has been emphasized, the selection of appropriate protective gear is based on the protection required. Appropriate protection is achieved by assembling a complete set of gear. This includes hardhat, safety glasses or faceshield (preferably both), body covering (coveralls or pants and jacket), gloves, and safety shoes (steel toe and shank). If one item is omitted, the safety of the individual is compromised.

Heat Stress & Body Cooling

With any clothing which provides protection aganist hazardous substances, it is important to recognize the hazards created by wearing such clothing. Because the body is shielded from normal circulation of air, it is not allowed to carry out its functions normally. Perspiration generated does not evaporate, thus eliminating the body's main mechanism of cooling. With that gone, the body is prone to heat stress which can be exhibited as heat stroke or heat exhaustion. This is very common as the ambient temperature rises above 65-70°F. Work schedules in fully encapsulated clothing must be regulated very conservatively as heat stress may become more of a threat than the chemical hazard itself.

The best way to combat any heat stress is to allow the body to perform its normal cooling functions. The most efficient body cooling process is by evaporation. While in protective clothing that has no ventilation, profuse perspiring occurs. If the perspiration is left in contact with the skin, it has a better chance of evaporating and cooling the body surface. When the perspiration is allowed to run off the body quickly, evaporation will not occur as much as is desirable. This will happen when only shorts are worn under a fully encapsulating suit. Another hazard when dressed minimally in a suit is the temperature of the suit itself. On a hot day the suit material can become very hot and cause severe burns to the person inside.

When wearing a fully encapsulating suit, it is advisable to wear long underwear. It will cling to the body when soaked with perspiration, thus allowing the greatest possible amount of cooling by evaporation. This will also protect the body from burns from the suit itself. The best way to prevent heat illness is to limit the amount of work in the suits.

When extended periods of work in fully encapsulated suits is required, some sort of cooling must be provided to the worker. The best method is by allowing frequent rest periods. Sometimes this is not enough so a cooling device must be employed. There are effective cooling units available for use with supplied air units. The cool air is directed to all parts of the body. A vortex tube is used to generate the cool air. Actually, the vortex tube separates the supplied air into warm and cool components and releases the warm air. When self-contained air is used for breathing, the cooling device must also be self-contained. Vests have been designed to carry ice packs for cooling. There are several other commercial devices available to combat heat generated by fully encapsulating suits.

Heat stress symptoms should be observed for all levels of protection, but especially in Levels A and B. For example, Army personnel wearing the military M3 toxicological suit (a two-piece butyl rubber suit) are required to follow these guidelines:

Ambient Temperature	Maximum Wearing Time (Hours)
Above 90°F	1/4 hour
85-90°F	1/2 hour
80-85°F	1 hour
70-80°F	1-1/2 hours
60-70°F	2 hours
50-60°F	3 hours
30-50°F	5 hours
Below 30°F	8 hours

Worker Monitoring

Besides normal safety monitoring, the use of fully encapsulating suits requires special monitoring of the wearer. Normally, monitoring is required when any respiratory apparatus is in use. But, because the use of fully encapsulating is warranted due to potential exposure to extremely toxic vapor atmospheres, it is especially important to assure that the wearer is properly protected. There are two methods of monitoring an individual in a fully encapsulating suit, biological monitoring and personal monitoring.

Biological monitoring is useful because it indicates what the actual exposure was to the worker. Prior to going on-site, a urine sample is taken. Its contents are compared to a sample after activity has ceased for the work period. The analysis should indicate any absorbed exposure due to hazard permeations or penetrations through the suit.

The use of personal monitoring measures the atmospheric concentrations within the suit. This gives an indication of potential body exposure. Personal sampling pumps equipped with charcoal tubes may be used to collect organic vapors. This type of pump must be worn underneath the encapsulating suit. If cotton socks or gloves are worn, their contents may be analyzed directly. Also, this will give an indication of potential exposure to the atmospheric hazard. This type of measurement is a qualitative indicator wheras use of the personal sampling pumps is quantitative.

Any exposure data is valuable when working with hazardous materials. Such data confirms or contradicts the criteria initially used in decision making for the selection of protective clothing.

Equipment List by Hazard Level

The following lists provide an inventory of necessary equipment needs in order to function in hazardous chemical environments:

Level A
Personal Protection Equipment

- Positive Pressure SCBA (MESA/NIOSH approved)
- Totally Encapsulating Suit (boots & gloves attached)
- Gloves - Inner (tight-fitting & chemical-resistant)
- Boots - Chemical protective, steel toe and shank. Depending on
- suit boot construction; worn over suit boot.
- Gloves - Outer, chemical protection. Depending on suit construction worn over suit gloves. May be replaced with tight-fitting, chemical-resistant gloves worn inside suit gloves.
- Underwear - Cotton, long john type*
- Hard hat* (under suit)
- Disposal protective suit, gloves, and boots. (Worn under or over encapsulating suit)*
- Coveralls* (under suit)
- 2-way Radio Communications

Level B
Personal Protective Equipment

- o Positive Pressure SCBA (MESA/NIOSH approved)
- o Two-piece chemical-resistant suit
- o Chemical-resistant hood*
- o Coveralls (fire-resistant) under splash suit*
- o Gloves - Outer, chemical protective
- o Gloves - Inner, tight-fitting, chemical resistant
- o Boots - Outer (chemical-protective heavy rubber throw aways)
- o Boots - Inner (chemical-protective, steel toe and shank)
- o 2-way Radio communications
- o Hard-hat*
- o Face Shield*

Level C
Personal Protective Equipment

- o Fullface, air-purifying respirator (MESA/NIOSH approved)
- o Chemical-resistant clothing: overalls & long sleeved jacket or coveralls, hooded 2-piece chemical splash suit, when applicable - hooded disposal coveralls*
- o Gloves - Outer (chemical-protective)
- o Gloves - Inner (surgical type)*
- o Cloth Coveralls - Fire-resistant (inside chemical protective clothing)*
- o Escape Mask
- o Hard-hat* (face shield, optional)
- o Boots - Outer (chemical-protective heavy rubber throw aways)*
- o Boots - Inner (chemical-protective, steel toe & shank)
- o 2-way Radio communications

Level D
Personal Protective Equipment

- o Coveralls - Fire-Resistant
- o Boots/Shoes - Safety or chemical-resistant steel toed boots
- o Boots - Outer (chemical-protective heavy rubber throw aways)*
- o Escape Mask
- o Safety Glasses
- o Hard-hat* (face shield optional)
- o Gloves*

*Optional Equipment

SECTION 19

INCIDENT EVALUATION

INTRODUCTION

The primary objective in responding to incidents involving hazardous substances is to prevent or reduce any actual or potential damage to public health or the environment. To accomplish this objective, it is necessary to:

- Identify the substance(s) involved.
- Evaluate its behavior in the environment and effects on public health and the environment.
- Initiate actions to ameliorate the effects.

Throughout a hazardous material incident, from inception to final disposition, a high priority activity is obtaining the necessary information to assess its impact. This process of identifying the actual or potential impact of the material(s) on public health, environment, and response personnel, and determining the most effective methods for preventing or reducing the associated hazards, is known as incident evaluation.

In those incidents where the substance(s) involved is known or easily identified, the media affected clearly ascertained, and the environmental effects recognized, the characterization of the incident is relatively straightforward. For example, the effects of a discharge of vinyl chloride into a small stream are relatively easy to evaluate. More complex are incidents such as an abandoned waste site where there is not enough initial information to identify the hazards and evaluate their impact.

Evaluating a hazardous substance incident is generally a two-phase process, Phase I, and initial evaluation, and Phase II, a comprehensive evaluation.

PHASE I: INITIAL EVALUATION

The first phase is an initial or preliminary evaluation based on information that is readily available - or can be collected fairly rapidly - to determine if emergency protective measures are necessary. During this initial phase, a number of key decisions must be made regarding:

- Imminent or potential hazard and risk to public health and/or the environment.

- Immediate need for protective actions to prevent or reduce the impact on public health and/or the environment.

- Health and safety of response personnel.

After emergency measures have been taken, other measures to restore the situation to environmentally acceptable conditions start. If there is no emergency, more time is available for acquiring data to evaluate hazards and design plans for cleanup, additional considerations for the health and safety of response personnel. Information for characterizing the hazards can be obtained in a variety of ways, depending upon the nature of the event and the amount of time available. The following outlines an approach for collecting the information needed to evaluate the impact of a hazardous materials incident. Not every incident requires following all the steps. The information below provides a relatively detailed guide which could be adapted to meet a specific situation.

Data Gathering and Review/Preliminary Assessment

Upon notification, discovery, or investigation of an environmental episode, obtain as much of the following information as possible:

- Brief description.
- Exact location.
- Date and time of occurrence.
- Current weather and forecast.
- Terrain - include topographic map.
- Geology and hydrology - include appropriate maps.
- Aerial photographs.
- Habitation - population centers, proximity of people, population at risk.
- Communications.
- Accessibility by air and roads.
- Waterways.
- Detailed description of incident and circumstances.
- Pathways of dispersion.
- Hazardous materials involved and their physical/chemical properties.
- Any other related background information.

- Present status of incident and who has responded.

- Environmentally sensitive areas - endangered species, delicate ecosystems.

- Economically sensitive areas - industrial, agricultural.

Information about an incident, especially abandoned waste sites, may also be available from:

- Other Federal agencies

- State and local health or environmental agencies.

- Company records.

- Court records.

- Water departments, sewage districts.

- State and local authorities.

Off-Site Reconnaissance

At responses in which the hazards are largely unknown or there is no need to go on-site immediately, make visual observations and monitor atmospheric hazards near the site. Also collect various types of off-site samples that may indicate on-site conditions. As an additional precaution, approach from upwind direction.

In addition to collecting information not included in the preliminary survey or needed to verify or supplement available information, off-site reconnaissance would include:

- General layout and map of the site.

- Monitoring ambient air for:

    -- organic vapors, gases, and particulates.

    -- oxygen deficiency.

    -- specific materials, if known.

    -- combustible gases.

    -- inorganic vapors, gases, and particulates.

    -- radiation.

- Placards, labels, markings on containers, or transportation vehicles.

- Types and numbers of containers, buildings, and impoundments.

- Leachate or runoff.
- Biological indicators - dead vegetation, animals, insects, and fish.
- Unusual odors or conditions.
- Visual observation of vapors, clouds, or suspicious substances.
- Off-site samples.
  - -- surface water
  - -- drinking water
  - -- site runoff
  - -- groundwater (wells)
- Interviews with inhabitants and indications of medical problems.

On-Site Survey

A more thorough evaluation of the hazards leading to remedial operations generally necessitates personnel entering the defined site. Prior to going on-site, develop an entry plan addressing what will be accomplished initially and prescribe the procedures to protect the health and safety of response personnel. Upon entering the site, collect the following information and observations:

- Monitoring ambient air for:
  - -- organic vapors, gases, and particulates.
  - -- oxygen deficiency.
  - -- specific materials, if know.
  - -- combustible gases.
  - -- inorganic vapors, gases, and particulates.
  - -- radiation.
- Types of containers, impoundment, or other storage systems.
  - -- numbers, types, and quantities of material
  - -- condition of storage systems, state of repair, or deterioration
- Physical condition of material.
  - -- solids, liquids, gases

- color, turbidity
  - behavior - foaming, vaporizing, corroding
- Leaks or discharges from containers, tanks, ponds, vehicles, etc.
- Potential pathways of dispersion.
  - air
  - surface water
  - groundwater
  - land surface
  - biological routes
- Labels, markings, identification tags, or other indicators of material.
- Samples.
  - standing water
  - soil
  - wells
  - storage containers
  - drainage ditches
  - streams and ponds

PHASE II: COMPREHENSIVE EVALUATION

The second phase, comprehensive evaluation, which may not be needed in all responses, is amore methodical program designed to collect data to enhance, refine, and enlarge the initial data base. This phase would provide more comprehensive information for characterizing the environmental hazards associated with incident response operations and for making decisions. As a continuously operating program, the second phase also reflects environmental changes resulting from response activities.

Available information and/or information obtained through initial site entries may be sufficient to identify and assess thoroughly the human and environmental effects of an incident. If not, additional monitoring and sampling are required. Phase II, an environmental surveillance program, will need to be designed and implemented to allow a complete evaluation of all the effects of the incident on all media. Also, since mitigation and remedial measures taken at the site may cause changes in the original conditions, a surveillance program must be maintained to identify any changes at the site. Phase II (which may not be required on all responses) is to refine, supplement, or complement information obtained through initial investigations and to maintain the surveillance program throughout the lifetime of the incident.

SUMMARY

Evaluating the hazards associated with an incident involves various degrees of complexities. The release of a single, known chemical compound may represent a relatively simple problem. It becomes progressively more difficult to determine harmful effects as the number of compounds increases. Evaluation of the hazards associated with an abandoned waste site, storage tanks, or lagoons holding vast amounts of known or unknown chemical substances is far more complex than a single release of an identifiable substance.

Effectively accomplishing the major responsibility of response personnel, which is the protection of public health and the environment, requires a thorough characterization of the chemical compounds involved, their dispersion pathways, concentrations in the environment, and deleterious effects. A base of information is developed over the lifetime of the incident to assess the harmful effects and ensure that effective actions are taken to mitigate the release.

SECTION 20

FIELD SAMPLING AND ANALYSIS

Prior to deploying diving personnel at a hazardously contaminated water site, the OSC or MSO must obtain information as to the nature and concentration of materials and assess the risk to underwater divers. As was described in Section 16 on "Incident Evaluation", sample acquisition forms the basis for any response action.

At present, there are numerous accepted standardized methods for collecting environmental samples. Many of these methods are specified by industrial, governmental, or scientific organizations such as the American Society of Testing Materials (ASTM). Common publications which spell out specific sampling requirements for a particular analysis are Standard Methods for the Examination of Water and Wastewater and Methods for Chemical Analysis of Water and Waste. Sampling procedures can also be found in the Federal Register. If there is conflicting information, employ the most recent U.S. Government method.

Personnel collecting hazardous samples should use protective clothing and equipment to minimize exposure. The use of special collection equipment presents a problem. Limited information is available, and no universally accepted standardized methods have been devised for the collection of hazardous samples.

Sampling Equipment

Equipment to collect and contain hazardous samples should be:

- Disposable or easily decontaminated. A collection device may be reused again only after thorough cleaning.
- Inexpensive, especially for disposable items.
- Easy to operate, because personnel may be wearing cumbersome safety clothing and respiratory equipment.
- Non-reactive, so that it does not contaminate samples.
- Safe to use.

All information pertinent to field activities will be recorded in various forms: logbooks, sample tags, photographs, etc. Proper documentation and document control are crucial to enforcement actions, since the government's case in a formal hearing or criminal prosecution often hinges on evidence gathered by the Science Coordinator. Therefore, each field worker must keep detailed records of inspections, investigations, photographs taken, etc., and review all notes thoroughly before leaving the site.

The purpose of document control is to assure that all documents for a specific project are accounted for when the project is completed. Accountable documents include items such as logbooks, field data records, analytical records, and photos. Each document should bear a serial number and should be listed, with the number, in a project document inventory assembled at the project's completion. Waterproof ink must be used in recording all data in documents bearing serial numbers.

The first area of sampling is air monitoring for:

- Organic vapors, gases, and particulates,
- Oxygen deficiency,
- Specific materials (if known),
- Combustible gases,
- Inorganic vapors, gases, and particulates,
- Radiation.

Samples must also be taken of the contaminated water surface, mid-depth and bottom.

Allowing for free head space in the top of the water sample container, a number of air monitoring tests can be run on the aqueous sample.

A number of field instruments which are currently used analyze "ambient" air for percentage of the lower flammability limit of a vapor or gas in air, concentration of oxygen, or concentration of toxic vapors/gases. These devices come in two categories, general survey and specific survey, based on the type of sampling performed.

General survey instruments include:

- Combustible gas indicators
- Ultraviolet photoionization detector
- Flame ionization detection
- Century Systems Organic Vapor Analyzer
- Infrared Spectrophotometer
- Miran Infrared Spectrophotometer

Specific survey instruments are devices that measure a specific material. Oxygen meters and direct-reading colorimetric tubes are virtually always used at incidents involving hazardous substances.

Appendix B entitled "Air Monitoring and Survey Instruments" presents information on the characteristics of field instruments along with detailed explanations on the characteristics, capabilities, and limitations of these units.

A number of different types of devices and techniques are utilized for sampling at incidents involving hazardous substances. Using the correct liquid and solid materials samplers, selecting sample containers and closures, and preserving samples, are all critical in obtaining the necessary analytical data that will provide the OSC and MSO with the true perspective on the condition of the incident. Appendix C describes various sampling equipment and methods.

Hazardous Materials Spills Detection Kit

In order to facilitate rapid detection, a Hazardous Materials Spills Detection Kit, shown in Fig. 20.1, for performing non-specific tests with a broad response to many contaminants has been developed by the EPA. The kit is designed for use at spills when the identity of the contaminant is known and the important consideration is tracing the spill plume until countermeasures can be taken.

The Hazardous Materials Detection Kit can be carried by one person and is versatile enough to be modified for special applications. It contains a pH meter, conductivity meter, spectrophotometer, filter assembly, effervescent jar, miniature chromatographic columns, enzyme "tickets", and data sheets. The instrument components are battery-powered for field use, although the spectrophotometer and conductivity meter can be modified for 120- or 240-V a.c. operation using the adapter and cable that are provided. The kit has all the necessary instrumentation, equipment, and reagents that may be needed by a field investigator to detect and trace contaminants in waterways.

Hazardous Materials Detection Kits, which are commercially available, have been used during emergency responses to hazardous materials spills. Additional information about the kits may be found in the EPA report, EPA-600/2-78-055.

Hazardous Materials Identification Kit

There are nearly 300 materials classified as hazardous substances by EPA (Federal Register, February 16, 1979), and a field kit capable of rapidly and accurately identifying each of these substances would be too unwieldy to be practical. Thus, thirty-six representative hazardous materials (toxic metals, anions, organic compounds) were selected and a field kit was designed by the EPA to identify these and related substances.

The identification (ID) kit, shown in Fig. 20.1, consists of two major components: (1) an inverter/shortwave UV lamp unit for photochemical and thermal reactions and (2) a package with reagents and auxiliary equipment, including test papers, detector tubes, spray reagents, spot test supplies, and thin-layer chromatography apparatus. Equipment to facilitate the recovery of contaminants from water and soil is also included. The field identification kit contains detailed operating instructions and data cards for each of the 36 representative hazardous substances.

Identification of groups of contaminants, rather than quantification of specific substances, is the intended use of the identification kit. The ID kit can be used in conjunction with the Hazardous Materials Detection Kit, which contains a pH meter, spectrophotometer, conductivity meter, and other analytical equipment. Utilization of both kits can improve identification capability, particularly for inorganic materials. For example, cyanide and fluoride cannot be distinguished by the ID kit alone; however, when the kits are used concurrently, identification becomes possible.

Spills or discharges of toxic pesticides in waterways pose a serious threat to the aquatic environment and municipal water supplies. With the increased use of organophosphate pesticides, which are toxic at very low levels, precautions are needed to reduce this threat. Because of the stability of toxic organophosphate pesticides under "normal" environmental conditions, it is imperative to detect these hazardous compounds rapidly .

Cholinesterase Antagonist Monitor

Automatic systems have been developed to monitor water for the presence of organophosphate and carbamate insecticides. The principle used for detecting these cholinesterase-inhibiting toxic substances is based upon: (1) the collection of enzyme inhibitors on immobilized cholinesterase, (2) the chemical reaction of immobilized cholinesterase with a substrate, butyrylthiocholinesterase, in the presence of enzyme inhibitors, and (3) the electrochemical monitoring of substrate hydrolysis products.

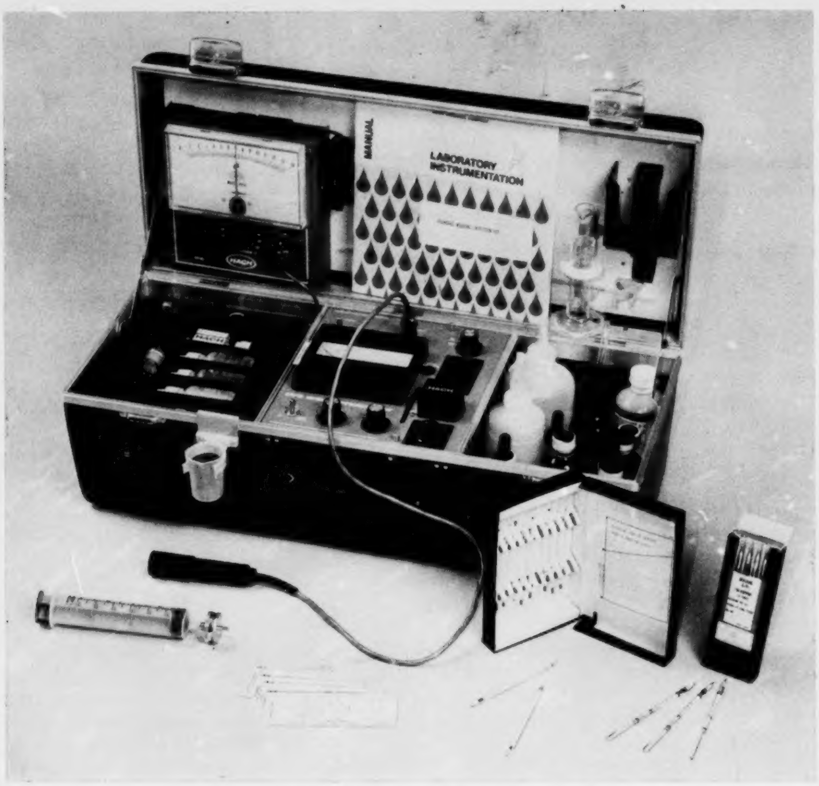
The Cholinesterase Antagonist Monitor (CAM-4), shown in Fig. 20.2 (developed by EPA) is a rugged instrument that is designed for rapid detection of toxic materials in a river, stream, or pond. The portable apparatus can be used from alongside the banks of a stream or from a boat. An operator is needed to note the presence of enzyme inhibitors when the baseline voltage increases 10 or more millivolts in one sampling cycle, as indicated on the printout of a strip chart recorder. The CAM-4 can operate continuously--with little maintenance--for an eight-hour period when using a 12-V automobile battery or a 110-V a.c. power source.

Cyclic Colorimeter

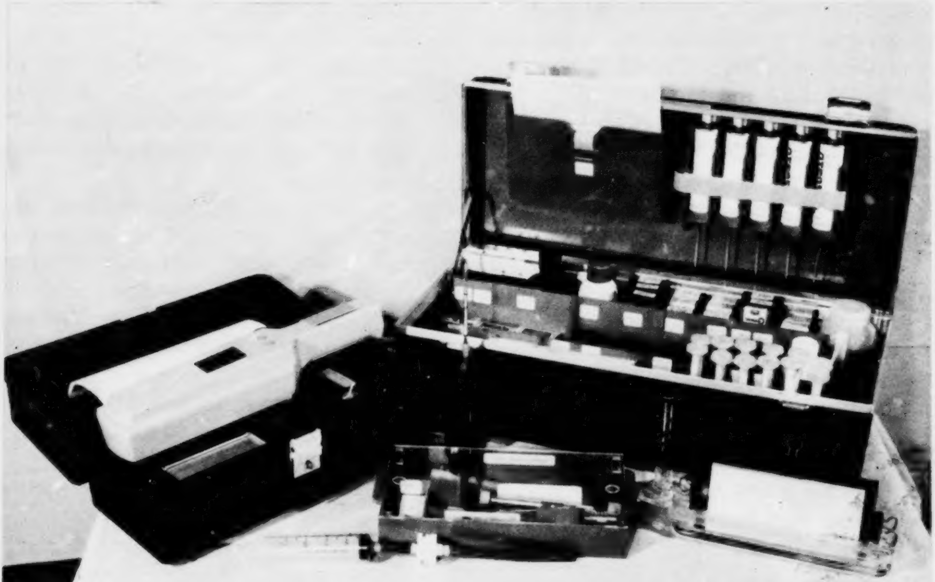
The Cyclic Colorimeter, shown in Fig. 20.2, (developed by the EPA) is useful for field monitoring of heavy metal spills. It incorporates hydraulic, optical, and electronic components that are designed for the automatic detection of most heavy metal pollutants. When an indicator, sodium sulfide, is injected dropwise into a sample stream, the presence of a heavy metal contaminant causes cyclic variations in optical transmittance at the indicator injection frequency. These variations are detected by a lamp and photocell, coupled to an electronic subsystem, which produces either a quantitative indication of the pollutant or an alarm when a threshold level is exceeded.

The Cyclic Colorimeter is capable of detecting low levels of many heavy metals in water of widely varying temperatures. The detector maintains adequate sensitivity for a period of about two weeks without maintenance. Scale buildup and stream turbidity do not affect its performance.

The Cyclic Colorimeter is commercially available. Instrument design specifications and descriptions of laboratory and field tests are included in the final report, EPA-600/2-79-064.

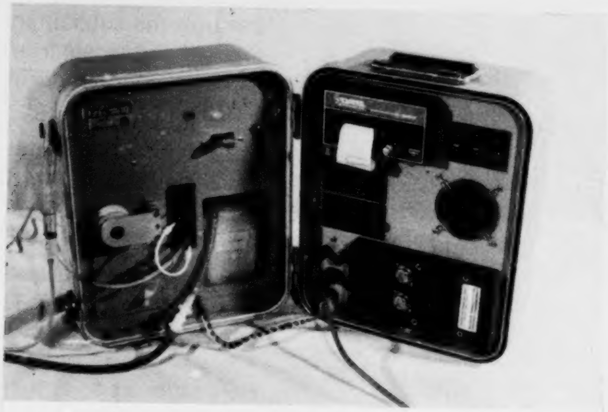


**Hazardous Materials
Detection Kit**



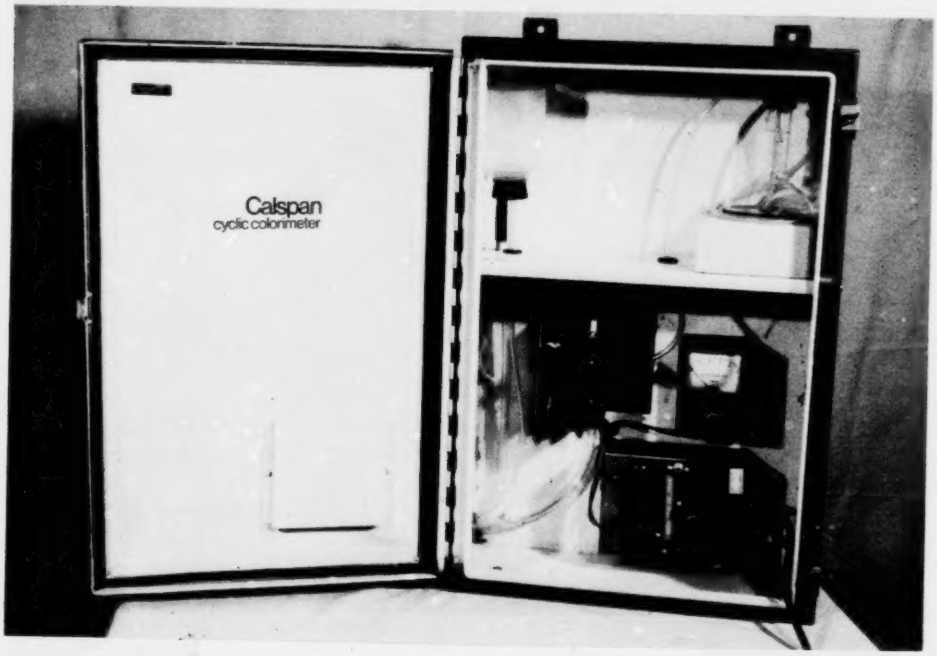
**Hazardous Materials
Identification Kit**

Figure 20.1



CAM-4

Pesticide Detection Apparatus



Cyclic Colorimeter

Figure 20.2

SECTION 21

HAZARD EVALUATION: "GO" OR "NO-GO"

Introduction

The utilization of encapsulating suits and helmets by diving personnel will permit underwater operations to be conducted in contaminated environments. There will, however, be response situations in which the hazardous substance(s) involved will present such a risk as to preclude the deployment of diving personnel except in dire emergency, for short periods of exposure, or not at all.

It is recognized that much of the toxicity data available today is based upon "pure product" contact. A diver in an underwater response operation will normally have the beneficial protection of his surrounding environment as an added buffer between him and the pure contaminant dilution.

In most large waterbodies currents, tides, and winds provide for water column "turnover" or mixing. A pure chemical product emanating from a point source, such as a drum, barge, ship discharge line, etc., will experience as rapid dilution from its original strength from even as close as a few feet from its origin. This is not to indicate that the diver or OSC should assume that "dilution is the solution."

Table 6.5 includes a number of hazardous substances which are "slightly soluble and insoluble sinking compounds." Materials such as these will accumulate in "pockets" and bottom depressions under no or low current conditions. Situations of diver response with the presence of these chemicals requires extra caution due to the "pure product" condition they can be encountered in underwater. A brief listing of these materials is as follows:

Acetic Anhydride
Acrylonitrile
Bromine
Cresol
Epichlorohydrin
Carbon Tetrachloride
Turpentine
Naphthalene
Hydrogen Sulfide
Methylene Chloride
Perchloroethylene
Dichloropropane

Methyl Parathion
Polychlorinated Biphenols
Trichloroethylene
Chlordane

Special caution should be exercised by diving personnel operating in "natural" polluted waterways which receive sewage and industrial runoff as opposed to a point source discharge of hazardous material. Hydrogen sulfide is a substance which is produced due to polluted and decomposing bottom benthos sediment. H_2S is a slightly soluble sinking compound which will accumulate in bottom depressions and which a diver can enter into easily without prior warning. The material exhibits a very high skin penetration and an extreme systemic hazard as well. Full encapsulation of the diver is required with as limited exposure as possible being exercised.

The second area in which a diver will come into contact with "pure product" is with "insoluble or slightly soluble floating" compounds which will be at the water surface and will coat the diver upon entry and exit from the operation site. Examples of such compounds are:

Benzene
Methyl Methacrylate
Styrene
Toluene
Chromium Salts
Ethylbenzene
Glycol Salicylate
Methyl Ethyl Ketone
Xylene

The use of a fire hose on the surface chemical slick will disperse the contaminant for the diver upon entering and leaving the water.

Of the 58 hazardous chemicals list in Table 6.6 of the U.S. Coast Guard's Pollution Incident Response System Data Base, 30 are listed in Table 21.1 entitled "Dermal Toxicity," and are noted by "★". Materials identified by the Navy and Environment Canada are identified by "✳" and "✶" respectively. All materials of concern identified by NOAA in Table 6.6 are incorporated in the other lists.

The approximately 350 chemicals listed in Table 21.1 are identified in the Oil and Hazardous Materials Technical Assistance System (OHMTADS) as being dermally active. Since OHMTADS contains only about 2100 chemicals, or may not indicate a listed chemical as a skin hazard, other reference sources should also be consulted.

Use of Tables

A. Categories

Table 21.1 divides chemicals into two categories:

Category 1 (more serious) which includes:

- Gases having a systemic dermal toxicity rating of moderate to extremely hazardous and a skin penetration ranking of moderate to high.
- Liquids and solids having a systemic dermal toxicity rating of extremely hazardous and a skin penetration ranking of moderate to high.
- Gases having a local dermal toxicity rating of moderate to extremely hazardous.
- Liquids and solids having a local dermal toxicity rating of extremely hazardous.

Category 2 (less serious) which includes:

- Gases having a systemic dermal toxicity rating of slightly hazardous and a skin penetration ranking of slight.
- Liquids and solids having a systemic dermal toxicity rating of slightly hazardous and a skin penetration ranking of moderate to slight.
- Gases having a local dermal toxicity rating of slightly hazardous.
- Liquids and solids having a local dermal toxicity rating of moderate to slightly hazardous.

B. Physical State

The physical state of the chemicals listed is their normal state. In a fire, some listed as solids or liquids could vaporize and represent a greater hazard to the skin. The chemicals listed also may be found mixed with other substances, which could change how they affect the skin.

C. Skin Penetration

-	Negligible Penetration (solid - polar)
+	Slight Penetration (solid - nonpolar)
++	Moderate Penetration (liquid/solid - nonpolar)
+++	High Penetration (gas/liquid - nonpolar)

D. Potency (Systemic)

			Lethal amount for a 70-kilogram man
+++	Extreme Hazard	(LD_{50}: 1 mg/kg-50 mg/kg)	drops to 20 ml
++	Moderate Hazard	(LD_{50}: 50-500 mg/kg)	1 ounce - 1 pint (1 pound)
+	Slight Hazard	(LD_{50}: 500-15,000 mg/kg)	1 pint - 1 quart (2.2 pounds)

E. Potency (Local)

+++ Extreme - Tissue distruction/necrosis

++ Moderate - Irritation/inflammation of skin

+ Slight - Reddening of skin

Relation of Table 21.1 and Levels of Protection

The purpose of Table 21.1 is to provide data that a qualified person can use in conjunction with other site-specific knowledge to select protective clothing. The data relate to skin toxicity only and should not be used to select respiratory protection equipment.

The known or suspected presence and/or measured concentration of Category 1 chemicals at or above the listed concentrations warrants wearing a fully encapsulating suit (Level A). The known or suspected presence and/or measured concentration of Category 2 chemicals at or above the listed concentrations suggests that a lesser level of skin protection (Level B or C) is needed.

There is no decision-logic for choosing protective clothing as there is for choosing respiratory protective equipment. The use of a fully encapsulating suit over other types of chemical-resistant clothing is generally a judgment made by a qualified individual based on an evaluation of all pertinent information available about the specific incident. Other guidance and criteria for selecting personnel protection equipment are contained in Appendix D, Interim Standard Operating Safety Guide.

Other References

Table 21.1 does not include all substances affecting the skin. Other standard references should be consulted, in particular:

- Threshold Limit Values for Chemical Substances and Physical Agents in the workroom Environment With Intended Changes for 1982, American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-5, Cincinnati, OH 45211 (1982).

Table 21.1. CHEMICAL DERMAL TOXICITY DATA

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
2,2 Dichloropropionic acid	solid	+	local	++	-	2
2,4,5 - T Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - T Amines	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - T Esters	solid	+	systemic local	+ +	10 mg/m^3/8h	2
2,4,5 - TP Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - TP Acid Esters	liquid	++	systemic local	+ +	10 mg/m^3/8h	2
2,4,5 - T Salts	solid	+	systemic local	+ +	10 mg/m^3/8h	2
2,4 - D Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4 - Dichlorophenol	solid	+	systemic local	+ ++	-	2
2,4 - D - Esters	liquid	++	systemic local	+ +	10 mg/m^3/8h	2
2 - Ethylhexyl Acrylate	liquid	++	local	+++	-	2
2 - Methyl - 5 - ethyl pyridine	liquid	++	local	+	-	2
2 - Napthol	solid	+	local	++	-	2
3,5 - Xylenol	solid	+	systemic local	++ +	-	2
Acetaldehyde	liquid	+	local systemic	++ +	200 ppm/8h 360 mg/m^3/8h	2
★ Acetic Anhydride	liquid	+	local systemic	++ +	5 ppm/8h 20 mg/m^3/8h	2
✽ Acetone	liquid	+++	local	++	1,000 ppm/8h 2,400 mg/m^3/8h	2
Acetone Cyanohydrin	liquid	++	systemic	+++	10 ppm/8h	1
★ Acetoacetone	liquid	++	local	++	-	2
Acetyl Bromide	fuming liquid	+++	local	+++	5 ppm/15 min	1
★ Acetyl Chloride	fuming liquid	+++	local	+++	5 ppm/15 min	1
Acridine	solid	+	local sensitizer	+++	-	2
Acrolein	liquid	+	local sensitizer	+++	0.1 ppm/8h .25 mg/m^3/8h	2
★ Acrylonitrile	liquid	+++	systemic local	+++ ++	2 ppm/8h	1

✽ - U.S. NAVY CONTRACT N60921-82-B-A052

✶ - ENVIRONMENT CANADA

★ - U.S. COAST GUARD POLLUTION INCIDENT DATA BASE

(Continued)

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Adipic Acid	solid	+	local	+	-	2
Adiponitrile	liquid	+++	systemic	+++	18 mg/m^3/8h	1
Alkyldimethyl 3,4 - Dichlorobenzylammonium Chloride	liquid	+	local	+	-	2
Allyl Alcohol	liquid	++	systemic local	++ ++	2 ppm/8h 5 mg/m^3/8h	2
Allyl Chloride	liquid	++	local	++	1 ppm/8h 3 mg/m^3/8h	2
★ Ammonia	gas	+	local	+++	25 ppm/8h 18 mg/m^3/8h	1
Ammonium Bicarbonate	solid	+	local	++	-	2
Ammonium Bichromate	solid	+	local	++	-	2
Ammonium Biflurride	solid	+	local	++	-	2
Ammonium Bisulfite	solid	+	local	+++	-	2
Ammonium Carbamate	solid	+	local	+	-	2
Ammonium Carbonate	solid	+	local	++	-	2
Ammonium Citrate (Dibasic)	solid	+	local	+++	-	2
Ammonium Ferrocyanide	solid	+	local	+	-	2
Ammonium Hydroxide	liquid	++	local	+++	-	1
✱ Ammonium Phosphate (Dibasic)	solid	+	local	++	-	2
Ammonium Sulfamate	solid	+	local	++	10 mg/m^3/8h	2
Ammonium Sulfide	solid	+	local	++	-	2
Ammonium Sulfite	solid	+	local	++	-	2
Ammonium Tartrate	solid	+	local	++	-	2
Ammonium Thiocyanate	solid	++	local systemic	+++ ++	-	2
Ammonium Thiosulfate	solid	+	local	++	-	2
Aniline	liquid	++	local	++	5 ppm/8h	2
Antimony	solid	+	systemic local	++ ++	0.5 mg/m^3/8h	2

(Continued)

Table 21.1. (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Antimony Pentachloride	liquid	++	local	+++	-	2
Argon - 37 (radioactive)	gas	+++	systemic	+++	-	1
Arsine	gas	+++	systemic	+++	0.05 mg/m^3/8h	1
Arsenic	solid	++	local systemic	+++ +++	.25 mg/m^3/8h	1
Arsenic-74 (radioactive)	solid	++	systemic	+++	-	1
Arsenic-76 (radioactive)	solid	++	systemic	+++	-	1
Arsenic-77 (radioactive)	solid	++	systemic	+++	-	1
Arsenic Acid	solid	++	local systemic	+++ +++	0.5 mg/m^3/8h	1
Arsenic Disulfide	solid	++	local systemic	+++ +++	-	1
Arsenic Pentoxide	solid	++	local systemic	+++ +++	-	1
Arsenic Tribromide	solid	++	local systemic	+++ +++	0.5 mg/m^3/8h	1
Arsenic Trichloride	solid	++	local systemic	+++ +++	0.5 mg/m^3/8h	1
Arsenic Trioxide	solid	++	local systemic	+++ +++	.25 mg/m^3/8h	1
Arsenic Trisulfide	solid	++	local systemic	+++ +++	0.5 mg/m^3/8h	1
Barium	solid	+	local	++	0.5 mg/m^3/8h	2
★ Benzene	liquid	++	local systemic	++ +++	75 ppm/30 min	1
Benzophenone	solid	+	local	++	-	2
Benzoyl Chloride	liquid	++	local	+++	5 mg/m^3/8h	1
Benzoyl Peroxide	solid	++	local	+++	5 mg/m^3/8h	1
Benzyl Alcohol	liquid	++	local systemic	++ +	-	2
Benzyl Benzoate	liquid	++	local	++	-	2
Benzyl Bromide	liquid	++	local	++	-	2
Benzyl Chloride	liquid	++	local	+++	1 ppm/8h	2
Beryllium Nitrate	solid	+	local	++	0.25 mg/m^3/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Brombenzylcyanide	liquid <77 F-solid	++	local systemic	++ +++	-	1
Calcium Hypochlorite	solid	+	local	++	-	1
✱ Calcium Oxide	solid	+	local	++	10 mg/m^3/30 min	2
Calcium Phosphide	solid	+	local	++	-	2
Camphor	solid	+	local systemic	++ ++	2 ppm/8h	2
Captan	solid	++	local systemic	++ ++	5 mg/m^3/8h	2
Carbaryl	solid	++	local systemic	+ ++	5 mg/m^3/8h	2
Carbofuran	liquid	++	local systemic	+++ +++	0.1 mg/m^3/8h	1
✱ Carbon Disulfide	liquid	++	local systemic	++ +++	20 ppm/8h 60 mg/m^3/8h	1
Carbon Monoxide	gas	+++	systemic	+++	50 ppm/8h	1
★ Carbon Tetrachloride	liquid	+++	systemic local	+++ +	10 ppm/8h	1
Cetyldimethylbenzyl-ammonium Chloride	solid	+	local	+	-	2
Chloracetophenone	solid	+	local systemic	++ ++	.05 ppm/8h	2
Chlordane	solid	+	local systemic	++ ++	.5 mg/m^3/8h	2
Bromine	liquid (fuming)	++	local systemic	+++ ++	.1 ppm/8h	1
Butylamine	liquid	++	local	+++	5 ppm/8h	1
Butyl Mercaptan	liquid	++	local	++	.5 ppm/8h	2
Butyric Acid	liquid	++	local	++	-	2
Calcium Arsenate	solid	+	local systemic	++ +++	1 mg/m^3/8h	1
Calcium Arsenite	solid	+	local systemic	++ +++	-	1
Calcium Carbide	solid	+	local	++	-	2
Calcium Cyanide	solid	++	systemic local	+++ ++	5 mg/m^3/10 min	1
★ Chlorine	gas	+++	local	+++	1 ppm/8h 3 mg/m^3/8h	1
Chlorine - 36 (radioactive)	gas	+++	local	+++	-	1

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Chloroacetic Acid	solid	++	local	++	-	2
Chlorobenzene	liquid	++	local systemic	++ ++	75 ppm/8h 350 mg/m^3/8h	2
Chlorobutadiene	liquid	++	local	++	25 ppm/8h	2
Chloromethane	gas	+++	local systemic	+ ++	100 ppm/8h	1
Chloropicrin	liquid	++	local	+++	0.1 ppm/8h	1
Chlorosulfonic Acid	liquid	++	local	+++	5 ppm/8h	1
Chlorthion	liquid	++	local systemic	+++ +	-	2
Chromyl Chloride	liquid	++	local systemic	+++ ++	.1 mg/m^3/8h	1
CMU	solid	+	local systemic	+ +	-	2
Copper Naphthenate	liquid	++	local systemic	++ ++	500 ppm	2
Coumaphos	solid	+	local systemic	++ +++	-	2
Cresyldiphenyl Phosphate	liquid	++	local	++	-	2
Crotonaldehyde	liquid	++	local systemic	++ ++	2 ppm/8h	2
Cumene	liquid	++	local systemic	++ +	50 ppm/8h	2
Cupric Acetate	solid	+	local systemic	+++ ++	0.1 mg/m^3/8h	2
Cupric Acetoarsenate	solid	+	local systemic	++ ++	0.1 mg/m^3/8h	2
Cupric Sulfate, Ammoniated	solid	+	local	++	2 mg/m^3/8h	2
Cyanogen	gas	+++	systemic local	+++ ++	10 ppm/8h	1
Cyanogen Bromide	solid	++	local systemic	+++ ++	0.5 ppm/8h	1
Cyanogen Chloride	gas	+++	local systemic	++ ++	10 ppm/15 min 5 mg/m^3/8h	1
✱ Cyclohexanol	liquid	+	local systemic	++ +	50 ppm/8h	2
Cyclohexanone	liquid	+	local systemic	++ +	50 ppm/8h	2
Cyclohexylamine	liquid	++	local systemic	++ ++	10 ppm/8h	2
Decaborane	solid	+	local systemic	++ ++	.05 ppm/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Decanal	liquid	++	local	++	-	
Diacetone Alcohol	liquid	++	local systemic	++ +	50 ppm/8h	2
Diamylamine	liquid	++	local systemic	++ ++	-	2
Diborane	gas	++	local systemic	++ ++	.1 ppm/8h	1
Dicamba	solid	+	local systemic	+ ++	-	2
Dichlobinil	solid	+	local systemic	+ +	-	2
Dichlone	solid	+	local	++	-	2
Dichlorodiflouromethane	gas	++	systemic	++	1,000 ppm/8h	2
Dichloroethyl Ether	liquid	++	local systemic	++ ++	5 ppm/8h	2
✱ Dichloromethane	liquid	++	local systemic	++ ++	200 ppm/8h	2
★ Dichloropropane	liquid	++	local systemic	++ +	75 ppm/8h	2
Dichloropropene	liquid	++	local systemic	++ ++	-	2
Dichloropropene Dichloropropane	liquid	++	local systemic	++ ++	-	2
Dichlorvos	liquid	++	systemic	++	.1 ppm/8h 1 mg/m^3/8h	2
Dicyclopentadiene	liquid	++	local	+++	5 ppm/8h	2
Diethanolamine	solid	+	local	++	-	2
Diethylamine	liquid	++	local	++	25 ppm/8h	2
Diethylene Glycol	liquid	+	systemic	+	-	2
Diethylenetriamine	liquid	+	local	+++	1 ppm/8h	2
Diethyl Phthalate; Ethyl Formate	liquid	++	local	+	-	2
★ Dimethylamine	oily liquid	++	local	+++	10 ppm/8h 18 mg/m^3/8h	2
N,N - dimethylaniline	oily liquid	+++	systemic local	++ +	5 ppm/8h 25 mg/m^3/8h	2
Dimethylsulfate	liquid	++	local	+++	1 ppm/8h	2
Dioxane (p-dioxane)	liquid	++	local systemic	++ +	50 ppm/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Diphosgene	gas	++	local	+++	-	1
Diquat		++	local systemic	++ ++	0.5 mg/m^3/8h	2
Disulfotone	liquid	++	systemic	+++	.1 mg/m^3/8h	1
Diuron		++	local systemic	++ ++	-	2
DNBP		++	systemic	+++	-	2
DNBP-NH$_4$-salt		++	systemic	+++	-	2
1-Dodecanol	solid	+	local	+	-	2
Endosulfan	solid	++	systemic	+++	0.1 mg/m^3/8h	2
Endothal			local	++		
★ Epichlorohydrin	liquid	++	local systemic	+ ++	5 ppm/8h 19 mg/m^3/8h	2
Ethion	liquid	++	systemic	++	-	2
Ethyl Acetate	liquid	++	local	++	400 ppm/8h 1400 mg/m^3/8h	2
Ethyl Acrylate	liquid	++	local systemic	++ ++	25 ppm/8h 100 mg/m^3/8h	2
★ Ethyl Benzene	liquid	++	local systemic	++ ++	100 ppm/8h	2
Ethyl Chloride	liquid	++	local frostbite	++	1,000 ppm/8h	2
* Ethylene	gas	++	local frostbite	++	-	2
Ethylene Cyanohydrin	liquid	++	systemic	+	-	2
Ethylene Dibromide	liquid	++	local systemic	++ ++	20 ppm/8h 50 ppm/5 min	2
* Ethylene Dichloride	liquid	++	local systemic	++ ++	10 ppm/8h 200 ppm/5 min	2
★ Ethylene Glycol Diacetate	liquid	++	systemic	+	-	2
★ Ethylene Glycol Monoethyl Ether Acetate	liquid	++	systemic local	+ +	100 ppm/8h	2
★ Ethylene Glycol Monoethyl Ether	liquid	++	systemic	+	25 ppm/8h	2
* Ethylene Oxide	liquid	+	local	+++	50 ppm/8h	2
* Ethyl Ether	liquid	+	local	+++	400 ppm/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Ferbam	solid	+	local systemic	+ +	15 mg/m^3/8h	2
Ferric Hydroxide	solid	-	local	++	-	2
Ferric Nitrate	solid	-	local	++	1 mg/m^3/8h	2
Ferric Sulfate	solid	-	local	++	-	2
Ferrous Sulfate	solid	-	local	++	-	2
Ferrous Hydroxide	solid	-	local	++	-	2
Ferrous Sulfite	solid	-	local	++	-	2
Fish Oil	liquid	++	local allergen	+	-	2
Fluorine	gas	+++	local	+++	.1 ppm	1
* Formaldehyde	liquid	++	local systemic	+++ ++	3 ppm/8h	2
* Formic acid	liquid	++	local	+++	5 ppm/8h	2
Furfural	liquid	++	local	+++	5 ppm/8h	2
Gas oils	liquid	++	local	+	-	2
Glyoxal	liquid	+	local	+	-	2
Guthion	solid	++	systemic	++	-	2
Heptachlor	solid	+++	systemic local	++ +	.5 mg/m^3/8h	2
Heptane	liquid	++	local systemic	+ ++	500 ppm/8h	2
Heptanol	liquid	++	local systemic	+ ++	-	2
HETP	liquid	+++	systemic	+++	-	1
Hexaborane	liquid	++	local systemic	++ ++	-	2
Hexamethylenediamine	solid	++	local systemic	+++ ++	-	2
* Hexane	liquid	++	local systemic	+ ++	500 ppm/8h	2
Hexanol	liquid	++	local	+++ ++	-	2
Hexylene Glycol	liquid	++	local systemic	++ +	25 ppm/8h 125 mg/m^3/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Hydrazine	liquid	++	local systemic	+++ ++	1 ppm/8h	1
★ Hydrochloric Acid	liquid	++	local systemic	+++ +	5 ppm/8h	1
★ Hydrofluoric Acid	liquid	++	local systemic	+++ +	3 ppm/8h	1
^{3}H (Tritium) (Radioactive)	gas	+++	systemic	+++	-	1
Hydrogen Cyanide	gas	+++	systemic	+++	10 ppm/8h	1
✳ Hydrogen Fluoride	gas	+++	local	+++	3 ppm/8h	1
✳ Hydrogen Sulfide	gas	+++	systemic	+++	10 ppm/8h	1
Hydroquinone	solid	++	local systemic	++ ++	2 mg/m^3/8h	2
Hypochlorous Acid	liquid	++	local	+++	-	2
Indole	solid	++	local	+++	-	2
Iron Dust	solid	-	local	++	-	2
Isobutyl Alcohol	liquid	++	local systemic	+ ++	100 ppm/8h	2
Isobutyraldehyde	liquid	++	local systemic	+++ +	-	2
Isobutyric Acid	liquid	+	local systemic	+++ +	-	2
Isophorone	liquid	++	local systemic	++ ++	25 ppm/8h	2
Isophthaloyl Chloride	solid	+	local systemic	++ +	-	2
Isopropyl Acetate	liquid	++	local systemic	+ +	250 ppm/8h	2
Isopropylamine	liquid	++	local systemic	++ ++	5 ppm/8h	2
Isopropyl Ether	liquid	++	local systemic	++ +	250 ppm/8h	2
Kepone	liquid	++	local systemic	+ ++	-	2
Krypton 85 (radioactive)	gas	+++	systemic	+++	-	1
★ Lead Arsenate	solid	+	local systemic	+ ++	.5 mg/m^3/8h	2
Lead Fluoborate	solid	+	local systemic	++ ++	-	2
Lindane	solid	++	systemic	++	.5 mg/m^3/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Malathion	liquid	++	systemic	+++	10 mg/m^3/8h	2
MCP	liquid	++	local systemic	+++ ++	-	2
Mercaptodimethur			systemic	++	-	2
Mercuric Cyanide	solid	+	local systemic	++ +++	.01 mg/m^3/8h	2
Mercuric Nitrate	solid	+	local systemic	++ +++	.05 mg/m^3/8h	2
Methacrylonitrile	liquid	++	local systemic	+ ++	1 ppm/8h	2
Methyl Acrylate	liquid	++	local systemic	+++ ++	10 ppm/8h	2
Methyl Amyl Acetate	liquid	++	local systemic	+ ++	50 ppm/8h	2
★ Methyl Amyl Alcohol	liquid	++	local systemic	++ +	25 ppm/8h	2
Methyl Bromide	liquid or gas	+	local	+++	20 ppm/8h	1
★ Methyl Chloride	liquid	+	local	+++	100 ppm/8h	2
★ Methylene Chloride	liquid	++	local systemic	++ ++	500 ppm/8h	2
★ Methyl Ethyl Ketone	liquid	++	local systemic	+ ++	590 mg/m^3/8h	2
Methyl Isobutyl Ketone	liquid	++	local systemic	+ +	100 ppm/8h	2
Methyl Mercaptan	gas	+++	local systemic	++ ++	10 ppm/8h	2
★ Methyl Methacrylate	liquid	++	local	+++	100 ppm/8h	2
★ Methyl Parathion	liquid	+++	systemic	+++	200 ug/m^3	1
Mexacarbate	solid	++	local systemic	+ +++	-	2
Monochloroacetone	liquid	++	local systemic	++ ++	-	2
Monochlorodifluoromethane	liquid	++	local (frostbite) systemic	+++ ++	1,000 ppm/8h	2
Monoethylamine	gas	+++	local	+++	10 ppm/8h	1
Monoisopropanolamine	liquid	++	local	++	-	2
Monomethylamine	gas	+++	local	+++	10 ppm/8h	1
★ Morpholine	liquid	++	local systemic	++ ++	20 ppm/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Mustard Gas	gas	++	local	+++	-	1
m-xylene	liquid	++	local systemic	++ +	100 ppm/8h	2
m-xylyl Bromide	liquid	++	local systemic	++ ++	-	2
Nabam	solid	++	local systemic	++ ++	-	2
Naled	liquid	++	local systemic	+ ++	3 mg/m^3/8h	2
n-amyl Acetate	liquid	++	local	++	100 ppm/8h	2
★ Naphthalene	solid	+	local systemic	++ ++	10 ppm/8h 50 mg/m^3/8h	2
Naphthenic Acid	solid	+	local	++	-	2
n-butyl Acetate	liquid	++	local	+	150 ppm/8h 710 mg/m^3/8h	2
n-butyl Acrylate	liquid	++	local	+++	-	2
n-butyl Alcohol	liquid	++	local systemic	++ +	50 ppm/8h	2
n-butyraldehyde	liquid	++	local	+++	-	2
Nickel Ammonium Sulfate	solid	+	local	++	1 mg/m^3/8h	2
Nickel Carbonyl	liquid	++	local systemic	++ ++	.05 ppm/8h	2
★ Nitric Acid	liquid	+	local	+++	2 ppm/8h	1
Nitric Oxide	gas	++	local	+++	25 ppm/8h	1
Nitrilotriacetic Acid	solid	+	local	++	-	2
★ Nitrogen Dioxide	gas	++	local	++	5 ppm/15 min	1
✱ Nitrobenzene	liquid	++	local systemic	++ ++	1 ppm/8h 5 mg/m^3/8h	2
Nitrogen Chloride	liquid	++	local	++	-	2
Nitroglycerine	liquid	++	local systemic	++ ++	2 mg/m^3/8h	2
Ozone	gas	+	local systemic	++ ++	.1 ppm/8h	2
Nitrous Oxide	gas	++	local	+++	25 ppm/8h	2
Nonane	liquid	++	local	++	-	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
★ Nonyl Phenol	liquid	++	local	+++	-	2
n-propyl Alcohol	liquid	++	local systemic	+ +	200 ppm/8h	2
Omazene	solid	+	local systemic	++ ++	-	2
o-nitrophenol	solid	++	local systemic	+++ +	-	2
o-nitroaniline	solid	+	local systemic	+ +++	-	2
Oxydipropionitrile	liquid	++	systemic local	++ +	-	2
o-xylene	liquid	++	local systemic	+ +	100 ppm/8h	2
para-nitroaniline	solid	+	local systemic	++ ++	1 ppm/8h	2
Pentanal	liquid	++	local systemic	++ +	-	2
Perchloromethyl mercaptan	liquid	+++	local systemic	++ ++	.1 ppm/8h	2
Phenolcarbylamine Chloride	liquid	++	local	++	-	2
Phenolmercuric Acetate	solid	+	local systemic	+ +++	-	2
Phosgene	gas	+	local	+++	.1 ppm/8h	1
White Phosphorous (yellow)	solid	+	local systemic	+++ ++	-	1
✳ Phosphorous Oxychloride	liquid	++	local systemic	+++ ++	-	2
Phosphorous Pentasulfide	solid	+	local systemic	+++ ++	1 mg/m^3/8h	2
✳ Phosphorous Trichloride	liquid	++	local systemic	+++ ++	.5 ppm/8h 3 mg/m^3/8h	2
Phthalic-Acid-Diethyl-Ester	liquid	++	local	+	-	2
Phthalic Anhydride	solid	+	local systemic	++ +	1 ppm/8h	2
p-nitrophenol	solid	+	local systemic	++ ++	-	2
Potassium Arsenate	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
Potassium Arsenite	solid	+	local systemic	++ +++	-	2
★ Potassium Permanganate	solid	+	local	+++	-	2
Propane	gas	++	local frostbite	+++	1,000 ppm/8h	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Propargite			systemic	++	-	2
Propionaldehyde	liquid	++	local	+++	-	2
Propionic Acid	liquid	++	local	++	10 ppm/8h	2
Propionic Anhydride	liquid	++	local	+++	-	2
Propyl Acetate	liquid	++	local	++	200 ppm/8h	2
Propylamine	liquid	++	local systemic	+++ ++	-	2
★ Propylene	gas	+++	local	+	4,000 ppm/8h	2
★ Propylene Oxide	liquid	++	local	++	100 ppm/8h	2
★ p-xylene	liquid	++	local systemic	++ +	100 ppm/8h	2
Pyrethrin I	liquid	++	local (allergen) systemic	+ +	-	2
Pyrethrin II	liquid	++	local (allergen) systemic	+ +	-	2
Pyrethrum	solid	+	local (allergen) systemic	++ ++	5 mg/m^3/8h	2
Pyridine	liquid	++	local systemic	++ +	5 ppm/8h	2
Pyrocatechol	solid	+	local systemic	++ +	1 ppm/8h	2
Quinhydrone	solid	+	local systemic	++ +	-	2
Quinine	solid	+	local systemic	+ +	-	2
Quinolene	liquid	++	local systemic	++ ++	-	2
Quinone	solid	+	local systemic	++ ++	.1 ppm/8h	2
Resorcinol	solid	+	local systemic	+++ ++	10 ppm/8h	2
Salicyaldehyde	liquid	++	local systemic	++ +	-	2
sec-Butylamine	liquid	+	local systemic	+++ ++	15 mg/m^3/8h	2
Selenium	solid	+	local systemic	++ ++	-	2
Selenium 75 (Radioactive)	solid	+	local systemic	++ +++	-	2
Sesone	solid	+	local systemic	++	-	2

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Silver Nitrate	solid	+	local systemic	++ ++	-	2
Simazine	liquid	++	local systemic	+ +	-	2
Sodium Anthraquinone Sulfonate	solid	+	local	++	-	2
Sodium Arsenate	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
Sodium Arsenite	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
★ Sodium Bisulfite	solid	+	local	++	-	2
Sodium Borate	solid	+	local systemic	++ +	-	2
Sodium Butyldiphenyl Sulfonate	liquid	++	local	++	-	2
Sodium Decylbenzene Sulfonate		+	local systemic	+ ++	-	2
Sodium Fluoride	solid	+	local	++ +++	2.5 mg/m^3/8h	2
Sodium Fluorosilicate	solid	+	local	++	2.5 mg/m^3/8h	2
Sodium Hydrosulfite	liquid	++	local	+++	-	2
Sodium Hypochlorite	liquid	++	local	+++	-	2
Sodium Lauryl Sulfate	solid	+	local	++	-	2
Sodium Methylate	solid	+	local	++	-	2
Sodium Naphthalene Sulfate		+	local systemic	+ ++	-	2
Sodium Nitrite	solid	+	local systemic	++ ++	-	2
Sodium Octylsulfate	solid	+	local	+	-	2
Sodium Selenite	solid	+	local systemic	++ ++	.2 mg/m^3/8h	2
Strychnine	solid	+	local systemic	++ +++	.15 mg/m^3/8h .45 mg/m^3/15 min	2
★ Styrene	liquid	++	local systemic	++ ++	100 ppm/8h 125 ppm/8h	2 2
Sulfoxide	solid	+	local	+	-	2
✶ Sulfur	solid	+	local	++	-	2
✶ Sulfur Dioxide	gas	+++	local	+++	5 ppm/8h	1

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
★ Sulfuric Acid	liquid	++	local	+++	1 mg/m^3/8h	1
Sulfur Monochloride	liquid	++	local	+++	1 ppm/8h	2
TBA	solid	+	local systemic	+ ++	-	2
T-Butylhydroperoxide	liquid	+	local systemic	+ ++	-	2
TCA	solid	+	local systemic	++ ++	-	2
TDE	solid	++	systemic	+	-	2
Tert-butylamide	solid	+	local systemic	+ +	-	2
Tetraborane	liquid	++	local systemic	+++ +++	-	2
Tetradecanol	solid	+	local systemic	+ +	-	2
Tetraethylene Pentamine	liquid	+	local systemic	++ ++	-	2
Tetraethyl Pyrophosphate	liquid	++	local systemic	+ +++	-	2
Thallium	solid	+	systemic	+++	0.1 mg/m^3/8h	2
Thallous Nitrate	solid	+	systemic	+++	0.1 mg/m^3/8h	2
Thiophosgene	liquid	+	local	+++	-	2
Thiram	solid	++	local systemic	++ ++	5 mg/m^3/8h	2
Titanium 44	solid	+	local	+	-	2
Titanium Chloride	solid	+	local	++	-	2
★ Toluene	liquid	+	local systemic	+ +	100 ppm/8h 375 mg/m^3/8h	2
Toluene diisocyanate	liquid	+	local systemic	++ ++	.02 ppm/8h .14 mg/m^3/8h	2
Toxaphene	solid	++	local systemic	+ ++	.5 mg/m^3/8h	2
Trichlorfon	solid	++	systemic	++	-	2
* Trichloroethane	liquid	++	local systemic	++ ++	10 ppm/8h 45 mg/m^3/8h	2
Tricresyl Phosphate	liquid	++	local systemic	+ ++	-	2
Triethylaluminum	liquid	+	local	+++	-	1

Table 21.1 (Continued)

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Triethylene Glycol	liquid	++	local systemic	+ ++	-	2
Triethylenetetramine	liquid	++	local	+++	-	2
Trimethylamine Gas	gas	++	local	+++	25 ppm/8h	1
Trimethylamine Solution	liquid	++	local	+++	25 ppm/8h	2
Trinitrotoluene	solid	++	local systemic	++ +	1.5 mg/m^3/8h	2
Uranyl Nitrate	solid	+	local systemic	++ ++	.25 mg/m^3/8h	2
Vanadium Oxytrichloride	liquid	++	local systemic	+++ ++	5 ppm/15 min	2
Vapam	liquid	++	local systemic	++ +	-	2
★ Vinyl Acetate	liquid	++	local	++	10 ppm/8h 30 mg/m^3/8h	2
Vinyl Bromide	gas	+++	local systemic	+++ +++	200 ppm/8h	1
✳ Vinyl Chloride	gas	+++	local systemic	+++ +++	200 ppm/8h	1
Vinyl Ether	liquid	++	local systemic	++ ++	-	2
Xenon 133 (radioactive)	gas	+++	systemic	+++	-	1
Zinc Borate	solid	+	local	++	10 mg/m^3/8h	2
Zinc Chloride	solid	+	local	++	1 ppm/8h	2
Zinc Cyanide	solid	+	local systemic	+ +++	-	1
Zinc Hydrosulfite	solid	+	local	+++	-	2
Zinc Phenolsulfonate	solid	+	local	+++	-	2
Zinc Phosphide	solid	+	local systemic	++ ++	-	2

- NIOSH/OSHA Pocket Guide to Chemical Hazards, U.S. Government Printing Office, Washington, DC 20402 (August 1981).
- Registry of Toxic Effects of Chemical Substances, U.S. Government Printing Office, Washington, DC 20402 (1980).

Whenever possible, data in one reference should be cross-checked with other references.

"No-Go" Scenarios

The utilization of diving personnel in contaminated environments is to always be the "last resort" to get "the job done." Application of remotely operated samplers, bottom dredges, remotely operated underwater video systems, etc. are all to be considered prior to deploying divers. However, even if divers are the only means for accomplishing an underwater task, there are some instances in which the contaminates involved preclude the use of divers under extreme emergency conditions for either short durations of exposure, or not at all!

Based upon the chemical/water interface of materials found in the U.S. Coast Guard list in Table 6.6, and the Dermal Toxicity Data presented in Table 21.1, umbilical support encapsulated diver exposure to the following chemicals should be for as short a period of time as possible, and only in response to protection of public health, or massive environmental damage:

Cresol (Phenols)
Carbon Tetrachloride
Naphthalene
Hydrogen Sulfide
Methylene Chloride
Perchloroethylene
Dichloropropane
Polychlorinated Biphenyls
Trichloroethylene
Benzene
Methyl Methacrylate
Styrene
Toluene
Ethylbenzene
Xylene

The classification of the above chemical substances is based upon their insolubility in water, and a permissible level of concentration of between 10 PPM/8-hour period to 100 PPM/8-hour period. This list is by no means meant to be a complete categorization. Each chemical substance encountered at a spill site must be evaluated for solubility, permissible concentrations, and propensity to attack diving dress materials.

Examples of insoluble chemical substances in which a diver should never be allowed to operate are as follows:

- Acetic Anhydride
- Acrylonitrile
- Bromine
- Epichlorohydrin
- Methyl Parathion
- Chlordane

Again, this list is not complete! Selection of these chemicals are based upon their insolubility and permissible concentrations being less than 10 PPM/8-hour period.

The OSC and diving officer must consult specific chemical characteristics references in order to make an educated on-site decision on whether or not to deploy diving personnel.

SECTION 22

GENERAL DIVING AND EMERGENCY PROCEDURES

Adherence to established diving procedures and recognition of any special precautions that may be needed because of local conditions will enhance the safety of diving operations. Diving personnel should have a thorough understanding of the procedures described in this section. Poor procedures result not only in unnecessary and costly delays, but also may affect the success of a project and increase the probability of accidents.

PLANNING THE DIVING OPERATION

Definition of Mission and Goals

A clear definition of the mission and its goals is the first step. To establish an operational plan, all parties engaged in the project should participate, including those who will be diving and those engaged in non-diving roles. Resources, including divers, diving equipment, surface or underwater support platforms, and support equipment, should be determined. The data or samples to be gathered, work to be performed, or observations to be made should be identified, and the bottom time should be estimated as closely as possible.

DIVE TEAM ORGANIZATION

Dive Master

Dive masters have total responsibility for the safe and efficient conduct of diving operations. They must be experienced divers qualified to handle the requirements of the proposed dive. No diving should be conducted when the dive master is not present. The dive master's responsibilities are many, and include but may not be limited to:

- Overall responsibility for the diving operation
- Safe execution of all diving
- Preparation of a basic plan of operation
- Liaison with other organizations
- Selection of equipment
- Proper maintenance, repair, and stowage of equipment
- Selection, evaluation, and briefing of divers and other personnel
- Monitoring the progress of the operation and updating requirements as necessary
- Maintaining the diving log
- Monitoring of decompression (when required)

The dive master is responsible for the assignment of all divers to an operation and for ensuring that their qualifications meet the requirements of the dive. The dive master shall ensure that all divers are briefed thoroughly on the missions and goals of the operation. Individual responsibilities will be assigned each diver by the dive master. Where special tools or techniques are to be used, the dive master shall ensure that each diver is familiar with their application.

Training and proficiency dives should be made as necessary to ensure safe and efficient operations. During operations involving a large number of divers or in very complex dives, dive masters should perform no actual diving, but instead should devote their efforts to directing the operation.

Diving Medical Officer/Medical Technician

Though there are obvious advantages to having a qualified diving medical officer on site, this may not always be practical. As an alternative to a diving medical officer, an Emergency Medical Technician trained in the care of diving casualties may be utilized. An individual so trained is able to respond not only to emergency medical situations, but also is capable of communicating effectively with a physician located at a distance from the diving site. There are specialized courses available designed to train Emergency Medical Technicians in the care of diving casualties.

In the event that neither a physician nor a trained technician is available, the dive master should obtain the names and phone numbers of at least three diving medical specialists who can be reached for advice in an emergency. Emergency consultation is available on 24-hour call at the Navy Experimental Diving Unit, Panama City, FL 32407, telephone (904) 234-4351, 4353; the National Naval Medical Center, Naval Medical Research Institute, Bethesda, MD 20014, telephone (301) 295-0283; Brooks Air Force Base, San Antonio, Texas 78235, telephone (512) 536-3278; and the Dining Accident Network (Dan), Durham, North Carolina, telephone (919) 684-8111. Each of these services is referred to as a "Bends Watch," and is available to provide advice on the treatment of diving casualties. Diving personnel should be sure to obtain and keep the phone numbers of these facilities, especially if diving operations are to be conducted in remote areas.

Science Coordinator

On missions where diving is performed in support of scientific programs, a science coordinator may be needed. The science coordinator is the prime point of contact for all scientific aspects of the program, including scientific equipment, its use, calibration, and maintenance. Working with the dive master, the science coordinator briefs divers on upcoming missions and supervises the debriefing and sample or data accumulation after a dive.

Divers

Although the dive master is responsible for the overall diving operation, each diver is responsible for being in proper physical condition, for checking out personal equipment prior to the dive, and for thoroughly understanding the purpose and the procedures to be used for the dive. Divers also are responsible for using safe diving procedures and for knowing all emergency procedures. A clean water "dip" tank should be utilized prior to entering contaminated waters to assure proper seals and that no suit leaks are present. (See Figures 22.1 and 22.2)

Tenders for Surface-Supplied Diving

The tender must be qualified to tend divers independently and to operate all surface-support equipment. To use manpower efficiently, the tender may be a qualified diver used in a diver-tender rotation system. Though there is no specific requirement that tenders be qualified divers, they should be trained in theory and operational procedures by the divers and diving supervisors. Ideally, tenders should be trained by instructors and assigned to diving operations by the diving supervisors. A tender-assistant may assume a tender's responsibilities when he is under the direct supervision of fully qualified diving and tending personnel, and he may receive instruction in proper tending procedures during field operations. Another tender, diver, or qualified person should be assigned as communications person, console operator, timekeeper, record keeper, and diver's assistant. Tenders must also be adequately protected against chemical hazards both from splash and respiratory aspects as shown in Figure 22.3.

It is recommended that one qualified person be designated as standby diver, ready to enter the water promptly in an emergency. The standby diver may accept tender responsibilities in routine operations; in more complicated diving operations, however, the standby diver must be freed of all other duties.

Support Divers and Other Support Personnel

In most diving operations the number and types of support divers depend upon the size of the operation and the type of diving equipment used. As a general rule, those surface-support personnel working directly with the diver also should be qualified divers. Using unqualified personnel who do not understand diving techniques and terminology may cause confusion and unnecessary complications. Persons not qualified as divers can be used when the need arises only after they have demonstrated an understanding of diving procedures to a standard acceptable to the dive master.

Small-Scale Operations

For self-contained diving operations, a minimum of two divers should be used. In a small-scale operation where the complexity of the assigned task is minimal, the dive master may dive, and no surface support is required. For an operation of increased scope, or if the tasks to be performed under water become more complex, standby divers and even tenders may be required.

Selection of Surface-Support Platform

During the course of operations, divers will enter the water from platforms of various sizes and descriptions, ranging from samll, inflatable rubber boats to large research vessels. Barges, specially outfitted for diving, also may be used. (See Figure 22.3)

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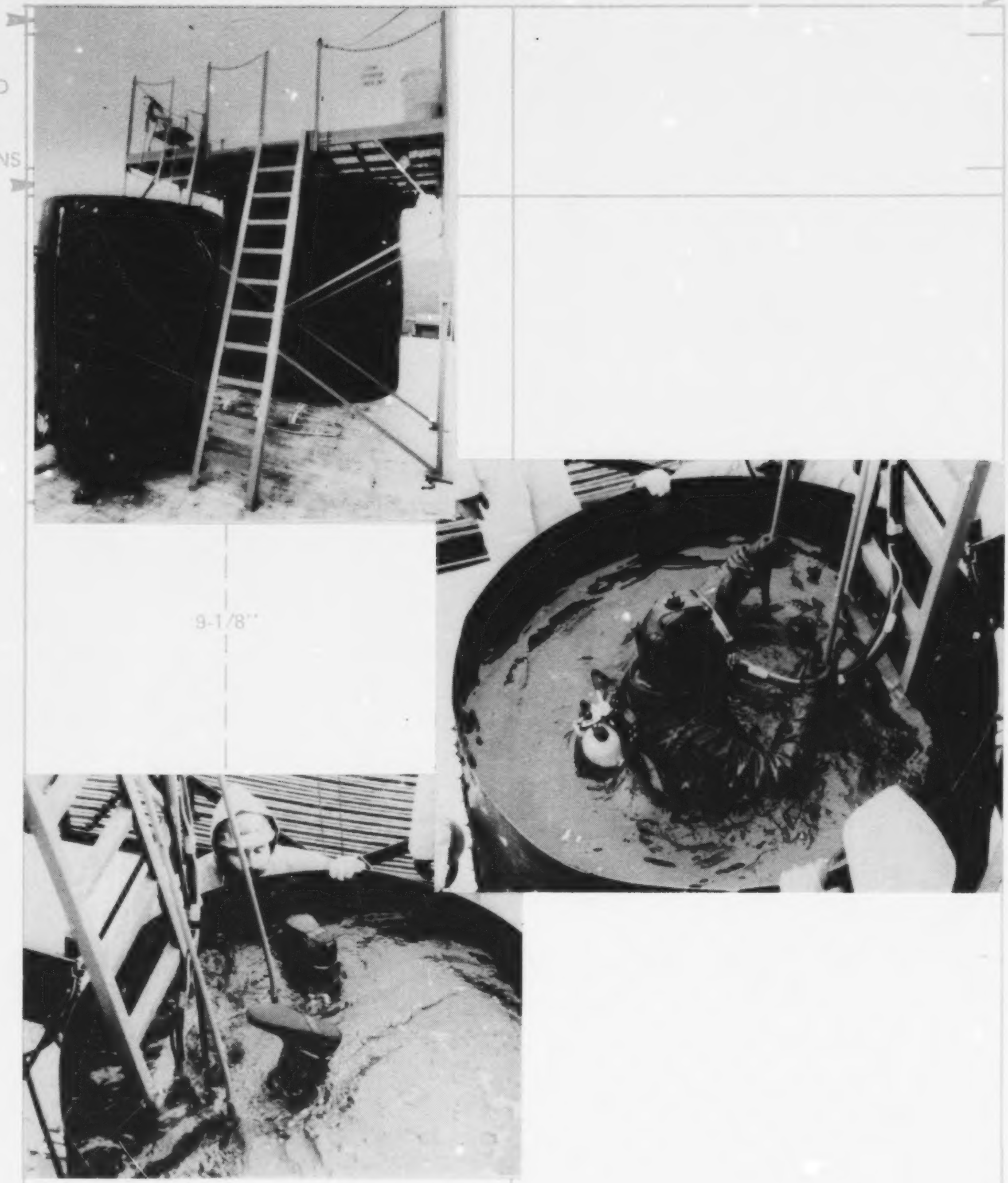

Figure 22.1 1000 Gallon "Dip" Tank for Leak Detection of Draeger Suit - OHMSETT

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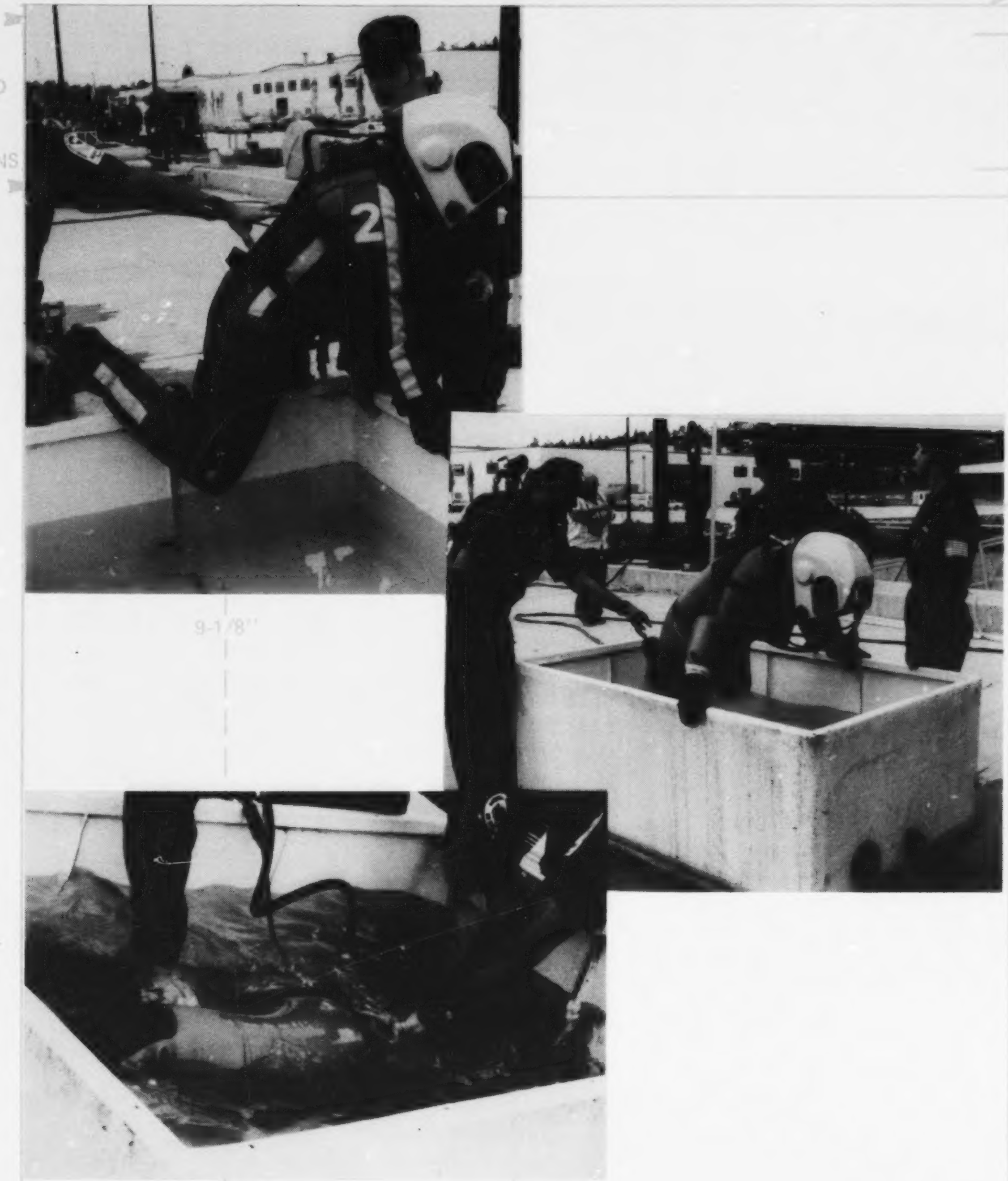

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Figure 22.2 300 Gallon "Dip" Tank for Leak Detection of MK-12 Suit

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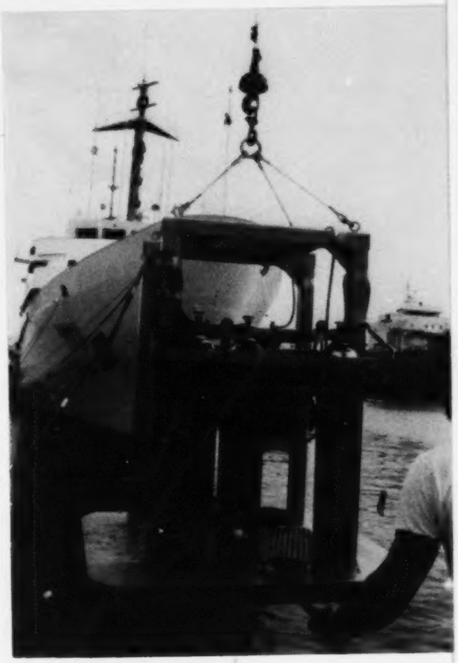
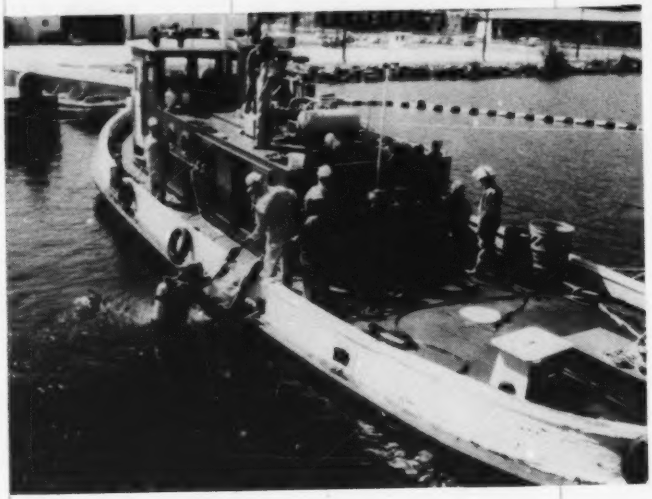
Dockside Operations



Diving Stage
Platform



Shipboard Operations

Figure 22.3 Surface-Support Platforms

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Generally, the operational requirements, type of diving equipment, magnitude of the diving task, and prevailing and predicted environmental conditions will dictate the best surface-support platform to use. For example, nearshore diving which uses self-contained equipment in relatively calm water may be accomplished without much difficulty from a small boat. More extensive offshore diving operations, using self-contained or umbilical-supplied equipment, would be undertaken from a large vessel with adequate deck space.

Environmental Conditions

Environmental conditions at a dive site should be considered in planning a diving operation. Generally, environmental conditions can be divided into surface environmental conditions and underwater environmental conditions. Surface conditions include weather, sea state, and ship traffic. Underwater conditions include depth, bottom type, currents, water temperatures, and visibility.

Surface Conditions--

Weather conditions are an important factor to consider in planning a dive. Whenever possible, diving operations should be cancelled or delayed during bad weather. Current and historical weather data should be reviewed to determine if proper conditions will prevail or are predicted for a sufficient amount of time to complete the mission. Critical weather changes and wind shifts may jeopardize the safety of personnel and platforms. All boaters should avail themselves of the continuous marine weather broadcasts provided by NOAA on the following frequencies: 162.40 MHz, 162.475 MHz, or 162.55 MHz, depending on the local area. These broadcasts can be heard in most areas of the U.S., and require only the purchase of a VHF radio receiver. VHF equipment comes in three levels of sophistication, ranging from the one- or two-band weather radios to multi-band radios and two-way sets. The weather radios are the least expensive and are designed to pick up NOAA radio broadcasts only.

Whenever possible, avoid or limit diving in moderate seas. Do not attempt scuba or surface-supplied diving in rough seas for a graphic representation of the various sea states. Sea state limitations depend to a large degree on the type and size of the diving platform. Diving operations may be conducted in rougher seas from properly moored larger platforms such as diving barges, ocean-going ships, or fixed structures. Divers using self-contained equipment should avoid entering the ocean in heavy surf. If bad weather sets in after a diving operation has commenced, appropriate recall signals should be employed.

Since many diving operations are conducted in harbors, rivers, or major shipping channels, other ships often present serious problems. At times, it may be necessary to close off an area or limit the movement of other ships. Ship traffic should be taken into consideration during dive planning and, if time permits, a local "Notice to Mariners" should be issued. Any time that diving operations are to be conducted in the vicinity of other ships, the other vessels should be notified of the diving by message or signal. For information on proper lights, shapes, and flags to be displayed during diving operations, see U.S. Coast Guard (1977).

If the operation will be carried on in the middle of an active fishing ground, small boats operated by people with various levels of experience and competence must be anticipated. The diving team should assume that these operators are not acquainted with the meaning of any diving signals, and should take the necessary precautions to ensure that they remain clear of the area.

Visibility--

Divers frequently are required to dive in water where visibility is minimal and sometimes at the zero level. Special precautions are appropriate when visibility is at zero or severely limited. If scuba is used, a buddy line or other reference system and float is recommended. A convenient way to attach a buddy line is to use a rubber loop that can be slipped on and off the wrist easily. This is preferable to tying a line, which would prevent rapid removal.

Heavy concentrations of plankton often accumulate at the thermocline, especially during the summer in the mid-Atlantic states. Divers may find that plankton absorb most of the light at the thermocline or that even though the water below the thermocline is clear, a light may still be required for visibility. Thermoclines in clear water diffuse light within the area of greatest temperature change, causing a significant decrease in visibility.

A sense of touch is extremely important to a diver or scientist working in low or zero visibility. The ability to use touch cues when handling tools or instruments in a strange work environment is valuable to a diver in the dark. Rehearsing work functions on the surface while blindfolded will increase proficiency in underwater tasks.

Underwater low-light-level closed-circuit television has been used successfully when light levels are reduced, because a television camera "sees" more in these conditions than does the human eye. This is true mainly when the reduced visibility is caused by the absence of light; in cases where the problem is caused by high turbidity, the TV camera does not offer a significant advantage. When the purpose of the dive is inspection or observation and a closed-circuit television system is used, the diver serves essentially as a mobile underwater platform. The monitor is watched by surface support personnel who, in turn, direct the movements of the diver. Underwater television cameras are available that are either handheld or mounted on a helmet.

Loss of Surface Air Supply--

A diver using umbilical-supplied equipment who experiences a loss of air supply usually has a limited amount of usable air left in the helmet or constant-volume suit. If the supply of air to the mask does not resume again quickly, the diver should signal the tenders, requesting to be brought to the surface, or should make a controlled ascent. The diver should not discard the diving equipment unless it is hopelessly fouled.

A self-contained emergency air supply system (come-home or bailout cylinder) may be used in conjunction with surface-supplied diving equipment. Such a system consists of a scuba cylinder assembly, a reduction regulator (first stage of a standard single hose regulator), and a backpack/harness assembly. Although the capacity of the scuba cylinder may vary from 10 to 140 cubic feet, many divers prefer to use a 40 to 50 ft^3 cylinder, rather than a large 72 ft^3 cylinder, for an emergency supply.

The first stage regulator used with the emergency air supply is fitted with a relief valve in the auxiliary low-pressure port to prevent over-pressure of the regulator to the mask hose in the event of regulator malfunction. Self-contained emergency air may be fed directly into the mask through a special attachment on the side valve or directly into the diver's air hose assembly. In the latter case, the check valve should be located between the intersection of the emergency gas supply hose and the primary surface supply hose.

For total redundancy, a completely separate scuba unit also may be used as a backup system. In this case the diver would ditch the helmet or mask in an emergency and insert the scuba regulator mouthpiece. This procedure is useful if the surface-supplied hose is badly tangled or the helmet or mask is not adapted for self-contained emergency air systems.

Another method commonly used by commercial divers is to have a standby diver with a spare hose available.

Flying after Diving at Sea Level--

Since specialized governmental diving units capable of hazardous response operations will not be located throughout the United States, it is fair to expect that dive team members will utilize air transportation as a means of arriving at the dive site. Flight planning following the completion of a dive operation must take into account the following information:

The elimination of inert gas from body tissues after an exposure to pressure continues for a period of 24 hours or more after the dive before equilibration with the ambient partial pressure of nitrogen in the air at the surface is completed. During this period, reducing the ambient pressure further will create a condition identical to that which occurs during decompression after a dive. After diving, divers should exercise caution when traveling in mountainous terrain as well as when flying. The cabin atmosphere in modern pressurized aircraft usually is maintained at an altitude of 8,000 feet (0.74 atmosphere), and this reduction in pressure may be sufficient to cause inert gas dissolved in a diver's tissues to come out in the form of bubbles, causing decompression sickness. This has occurred, with severe symptoms, in divers who fly after diving. Flying after diving is a recognized hazard that should be avoided. Termination of the flight, which increases the ambient pressure to 1 atmosphere, does not necessarily cause the gas bubbles to decrease sufficiently in size to stop causing symptoms. Recompression treatment may be required to relieve symptoms. Since a diver may have left the vicinity of a recompression chamber, it may be difficult to find a chamber in which treatment can be instituted. The delay that results may cause permanent tissue damage and extend treatment time.

If it is necessary to fly immediately after a decompression dive, a series of repetitive dives, or recompression treatment (as with an injury that requires medical capability beyond that available at the dive site), the diver should be transported at low altitude by helicopter or aircraft, or in a pressurized aircraft at a cabin atmosphere of not more than 800 feet of altitude. If it is necessary to transport by air a diver suffering from decompression sickness, the flight should be conducted at the lowest safe altitude possible or in a pressurized aircraft in which the cabin atmosphere does not exceed 800 feet of altitude. In addition, the victim should breathe pure oxygen until arrival at a recompression chamber.

Before flying in an aircraft in which the cabin atmosphere is less than 8,000 feet (usually the case in most flights), a diver who has completed any number of dives on air and been decompressed according to the U.S. Navy Standard Air Decompression Tables should wait at sea level, breathing air, for the computed surface interval that allows him to be classified as a Group D diver in the U.S. Navy Repetitive Diving Table.

Before flying, the diver should check with the flight engineer to ascertain the maximum planned cabin altitude and to inform him that divers will be aboard.

To shorten the necessary surface interval before flying, oxygen may be breathed instead of air. Table 22.1 lists the length of oxygen-breathing time necessary before flying is allowed, for the various Repetitive Dive Group classifications.

Table 22.1

Optional Oxygen-Breathing Times
Before Flying After Diving

Repetitive Dive Groups	Oxygen Time Before Flying (Hr:Min)
Groups M through Z	1:30
Groups H through L	1:00
Groups E through G	0:30
Groups A through D	0:00

SECTION 23

ADDITIONAL ON-SCENE RESPONSE CONSIDERATIONS

Access

The access for members of the news media into the operations must be determined by the OSC or MSO. A specific individual should be selected as the spokesperson for the release of all official information. All response team personnel are to direct inquiries from the news media to this individual. News people will generally go to any lengths to get a shot of site operations even if operations are in a hot contaminated area. For safety reasons, nonessential response team individuals and the public are to be kept away from the site during operations. Any "official" visitor must be accompanied at all times by a response team member while on-site. At the discretion of the OSC, the site and surrounding area may be evacuated of all personnel. Work with local law enforcement authorities. They are on your side (usually).

Physical Examinations

Only individuals who have received a complete physical examination within the past year should be permitted within "hot" contaminated operational work areas.

Weather

Consideration must be made as to sea state for any diving operation. Deployment and recovery of both diving personnel, gear, equipment, and salvaged items are greatly complicated by high seas. Diving personnel working in relatively shallow waters (10-15 feet) can also be susceptible to air embolism due to wave depth variances as small as four feet.

Wind and temperature should be closely monitored and wind chill calculations made every hour during cold weather. Surface-support personnel will be particularly prone to frostbite and exposure once they become wet.

Respiratory Protection

No individuals will be allowed inside the "hot" operational site without appropriate respiratory protection. Respirators, except during donning and removal, shall be either positive pressure SCBA's, umbilical airlines, or air purifying canister full-face mask units. All personnel wearing respirators must shave at the start of each work day to prevent leakage at the facepiece-to-face-seal.

Personal Hygiene

No one will be permitted to eat, drink, or smoke inside the fenced area. Outside the fence, they will thoroughly wash hands and face with soap and water before doing so. Individuals must wash hands with soap and water before urinating. All footwear worn inside the fence must remain on site until the field work is completed. At the end of each day, disposable clothing will be removed and disposed of in 55-gallon metal drums, which will remain inside the fence. Individuals are expected to shower promptly and thoroughly after leaving the site at the end of each day.

Personnel Exposure

If clothing is ripped or torn, it is to be removed and replaced as soon as possible. Disposable clothing contaminated with an observable amount of chemical residue is to be removed and replaced immediately. Residue on "moon suits" is to be washed off as soon as possible. In the event of direct skin contact, the affected area is to be washed immediately with soap and water and the person taken to a hospital. A person will be stationed in the decontamination area to assist in the removal of protective gear.

Hospital & Emergency Services

One response team member, stationed outside the "hot" operational area, must know the quickest route to local medical facilities. Contact should be made, prior to operations commencing, with the local first aid squad, hospital emergency room, and nearest operational recompression chamber. Contact with the area Coast Guard station is necessary if air/helicopter evacuation of injured divers must be made. Phone numbers of all emergency response and service organizations must be prominently displayed next to the command post telephone.

Fire

If the response operation involves flammable material, the local Fire Department must be contacted to assist in standing a "fire watch" just off-site during operations. Fire personnel must have had training in SCBA and should be prepared to spread foam (light water) in the event of a fire.

SECTION 24

DECONTAMINATION PROCEDURES

As part of the system to prevent or reduce the physical transfer of contaminants by people and/or equipment from on-site, procedures must be instituted for decontaminating anything leaving the Exclusion Area and Contamination Reduction Area. These procedures include the decontamination of personnel, protective equipment, monitoring equipment, clean-up equipment, etc. Unless otherwise demonstrated, everything leaving the Exclusion Area should be considered contaminated and appropriate methods established for decontamination.

In general, decontamination at the site consists of rinsing equipment, personnel, etc., with copious amounts of water and washing same with a detergent/water solution. If contaminants are known, then a specific detergent and/or solvent can be used to decontaminate. Fig. 24.1 illustrates the maximum physical layout for personnel decontamination during a worst case situation. Fig. 24.2 illustrates the minimum physical layout for personnel decontamination for a relatively small well-identified situation. Each site requires special consideration and the decontamination procedures should be modified from the maximum to minimum layout based on known information.

Decontamination (Decon) and Rinse Solutions

The decon solutions should be solutions of water and chemical compounds designed to react with and neutralize the specific contaminants. The temperature and contact time also should be considered in order to insure complete neutralization. An excellent unit for applying decon and surfactant solutions is a La-Pressure Washer, Model 914. The washer delivers 4 GPM at 1000 psi and can withdraw decon solutions via a siphon feed hose.

The contaminants will not always be known in a majority of cases and it will be necessary to use a decon solution that is effective for a variety of contaminants. Two of these general decon solutions are listed below:

- Decon Solution A - A solution containing 5% Sodium Carbonate (Na_2CO_3) and 5% Trisodium Phosphate (Na_3PO_4). Mix four (4) pounds of commercial grade Na_2CO_3 plus four (4) pounds commercial grade Na_3PO_4 with each ten (10) gallons of water. These chemicals are available at most hardware stores.

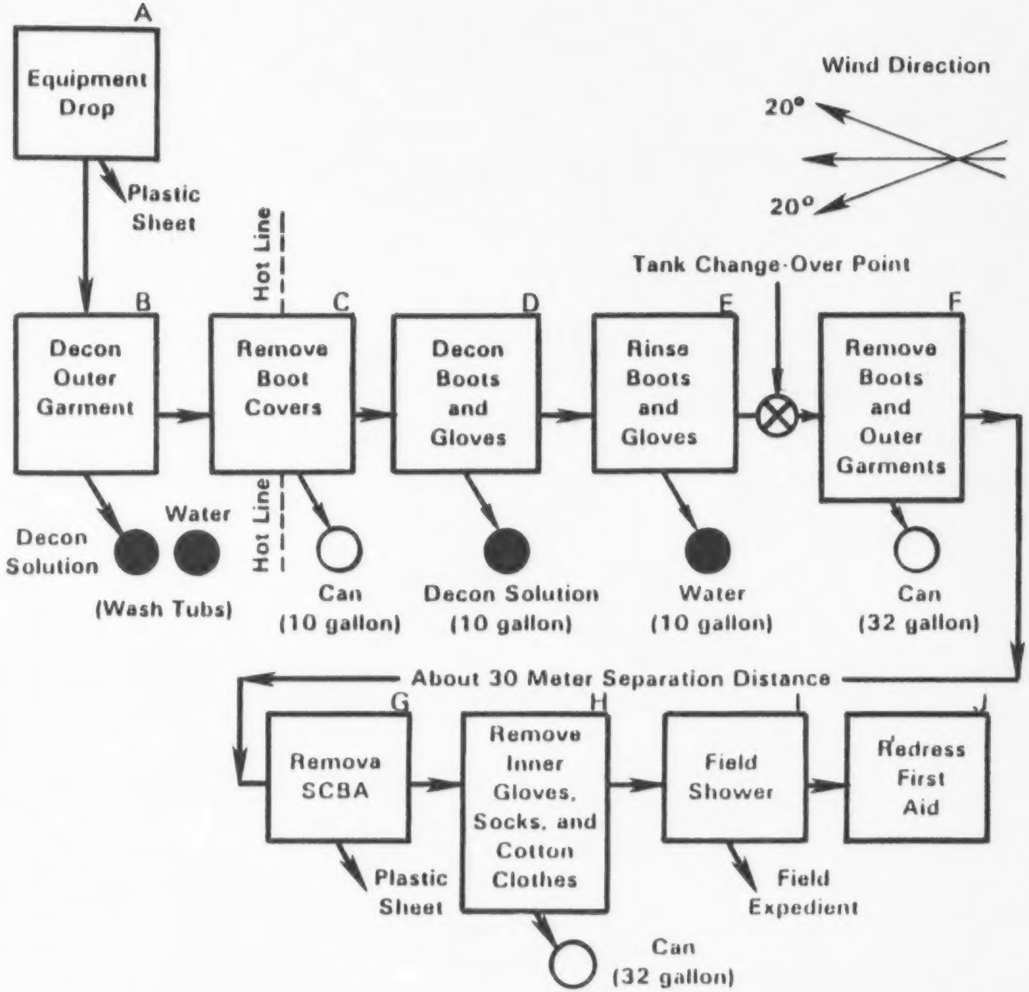

Figure 24.1 Maximum layout of personnel decontamination station. (Levels A & B Protection)

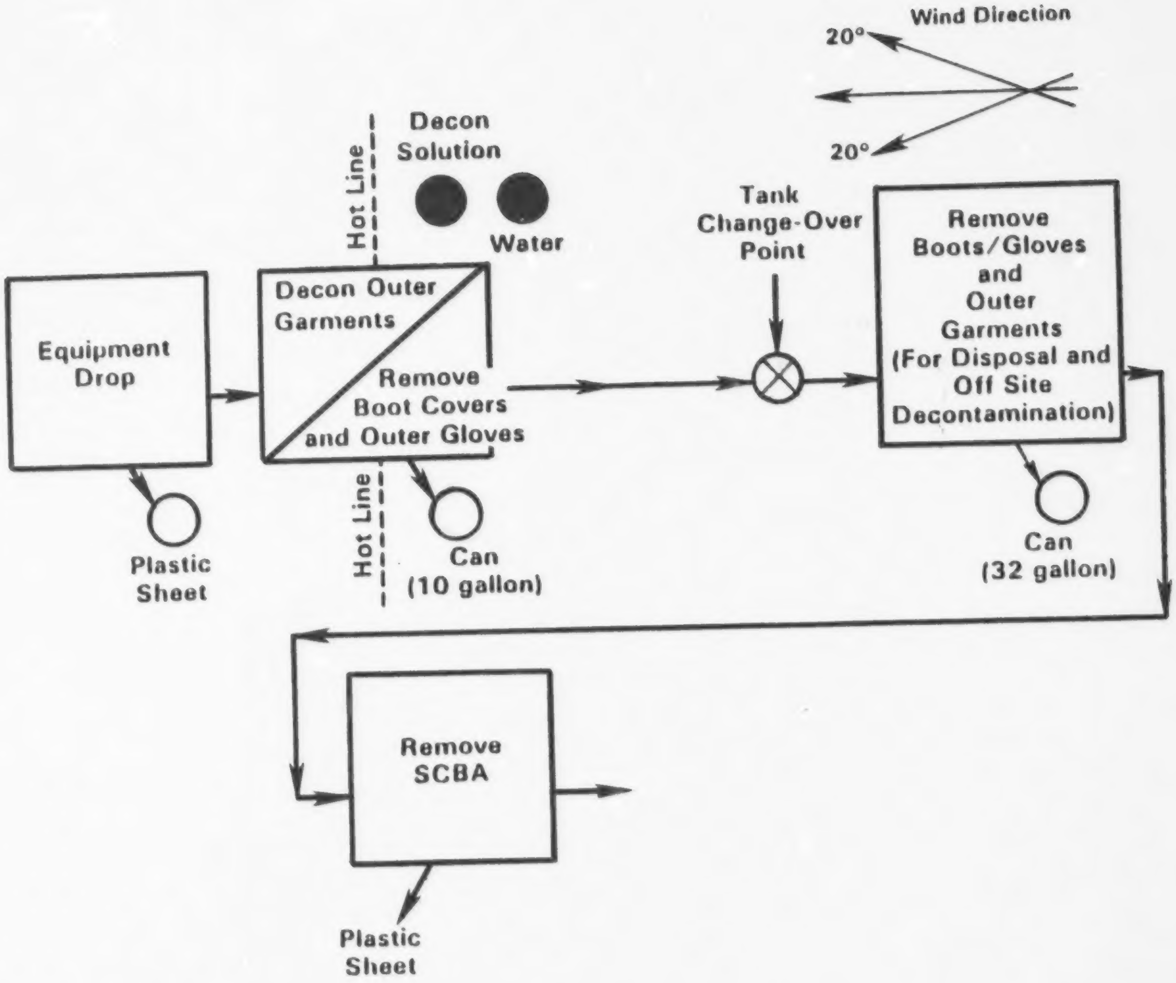

Figure 24.2 Minimum layout of the PDS.

(Level A, B & C Protection)

o Decon Solution B - A solution containing 10% Calcium Hypochlorite ($Ca(ClO)_2$). Mix eight (8) pounds of $Ca(ClO)_2$ with each ten (10) gallons of water. Calcium Hypochlorite (HTH) is available at most hardware or pool supply stores.

The rinse solutions used in decon should have the ability not only to remove the decon solution physically, but also to neutralize excess decon solution.

A general purpose rinse solution, used for both decon solutions listed above consists of a five (5) percent solution of Trisodium Phosphate. Mix four (4) pounds Na_3PO_4 with each ten (10) gallons of water.

A final rinse of liquid Ivory soap solution is recommended on all decon procedures followed by fresh water. (See Figures 24.3 and 24.4)

Operational Considerations

The decontamination procedures illustrated in Fig. 24.1 are for Level A protection which more often than not requires a detailed decontamination process during a worst case situation (i.e., Dioxin contamination, chemical fire, immediately dangerous to life or health atmospheres). Fig. 24.2 illustrates the minimum physical layout for personnel decontamination during a relatively small, well-defined situation (i.e., pesticide spill, solvent spill, etc.).

Less extensive procedures for decontamination can be subsequently or initially established when the type and degree of contamination through analysis becomes known or the potential for transfer is judged to be minimum. These procedures generally involve one or two washdowns only, and fewer precautionary measures in doffing equipment. These procedures would not involve additional decontamination of the protective clothing which is removed. Table 24.1 lists general decon solutions and their applications.

In extreme situations when there may be a question of the efficacy of decontamination to known or strongly suspect substances of a highly toxic nature, protective clothing may have to be discarded after use or tested after decontamination.

Consideration must also be given to the protective equipment worn by those personnel operating the decontamination line. In most cases, chemical protective clothing, boots, and gloves should suffice. Unless it is suspected and/or confirmed that personnel needing decontamination are highly contaminated, air-purifying respirators with suitable canisters can be worn (Level C Protection).

Decontamination solutions should be designed to react with and neutralize the specific potential contaminants involved in an incident. However, since the contaminants at an uncontrolled waste site will be unknown in the majority of cases, it is necessary to use a decontamination solution that is effective for a variety of contaminants. Several of these

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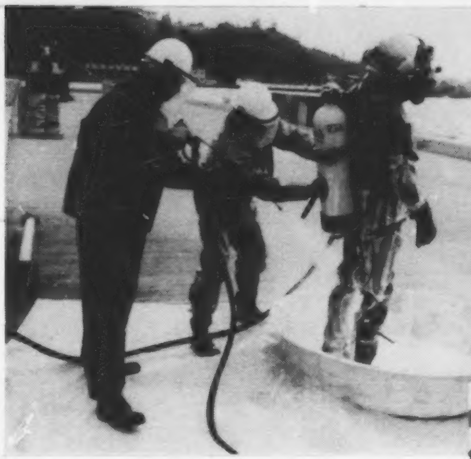
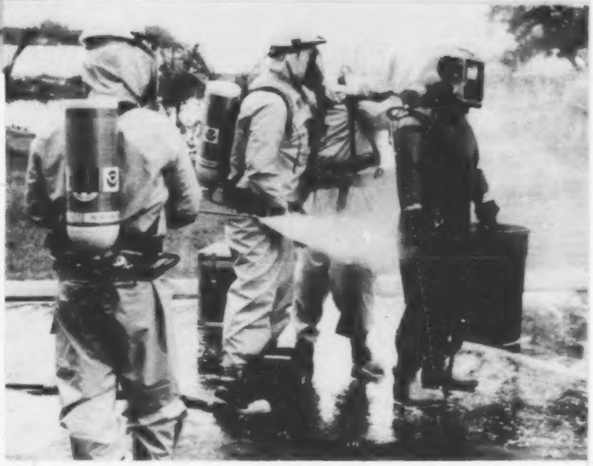
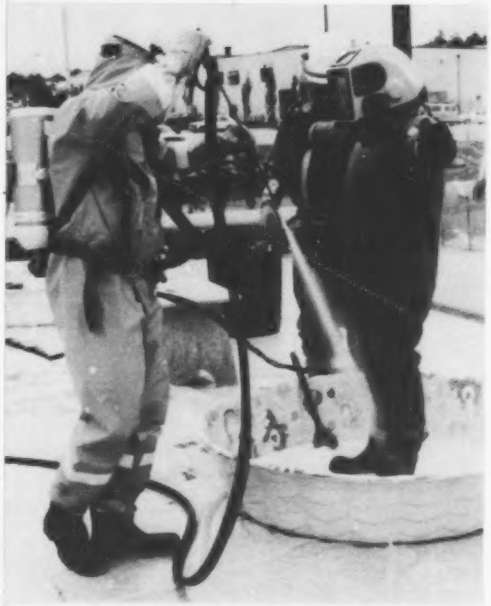


Dockside Decon of
Superlite 17 Rig



Gross Initial Washdown
of MK-12 Rig

6-1/2"



Final Decon of
MK-12 Rig

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Figure 24.3 Dockside Decon Operations

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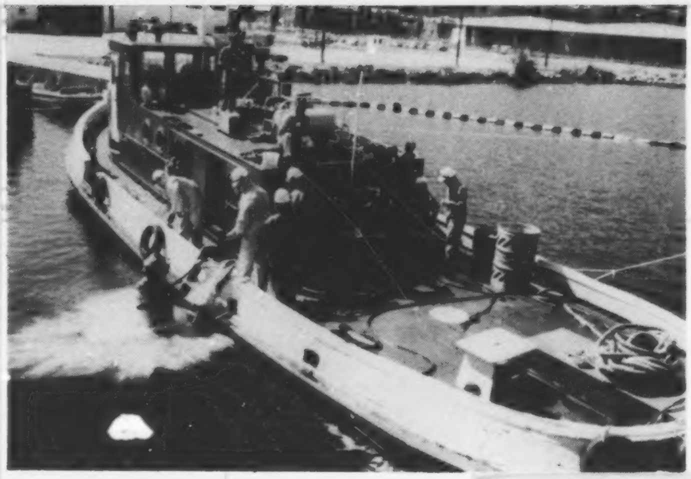
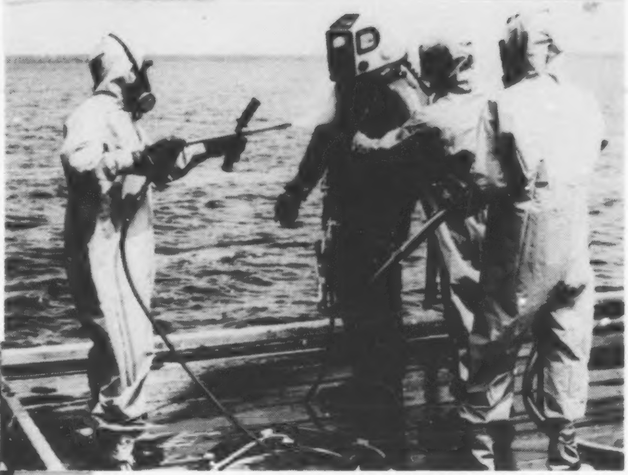
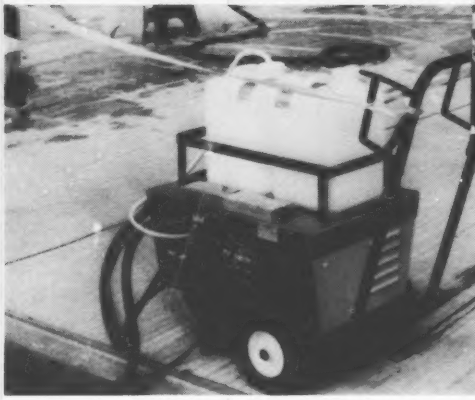


Initial Gross In-Water
Contaminant Washdown
of Superlite 17



Final Shipboard
Decon of MK-12 Rig



Pressure Washer w/
Concentrated Decon
Solutions

Figure 24.4 Shipboard Decon Operations

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Table 24.1 USES OF GENERAL PURPOSE DECON SOLUTIONS

TYPE OF HAZARD SUSPECTED	SOLUTION	INSTRUCTIONS
1. Inorganic acids, metal processing wastes.	A	To 10 gallons of water, add 4 pounds of sodium carbonate (soda lime) and 4 pounds of trisodium phosphate. Stir until evenly mixed.
2. Heavy metals: mercury, lead, cadmium, etc.	A	Same as #1 above.
3. Pesticides, fungicides, chlorinated phenols, dioxins, and PCB's.	B	To 10 gallons of water, add 8 pounds of calcium hypochlorite. Stir with wooden or plastic stirrer until evenly mixed.
4. Cyanides, ammonia, and other non-acidic inorganic wastes.	B	Same as #3 above.
5. Solvents and organic compounds, such as trichloroethylene, chloroform, and toluene.	C (or A)	To 10 Gallons of water, add 4 pounds of trisodium phosphate. Stir until evenly mixed.
6. PBB's and PCB's.	C (or A)	Same as #5 above.
7. Oily, greasy unspecified wastes.	C	Same as #5 above.
8. Inorganic bases, alkali, and caustic waste.	D	To 10 gallons of water, add 1 pint of concentrated hydrochloric acid. Stir with a wooden or plastic stirrer.

general purpose decontamination solutions (some ingredients are available at hardware or swimming pool supply stores) are listed below:

- Decon Solution A - A solution containing 5% Sodium Carbonate (Na_2CO_3) and 5% Trisodium Phosphate (Na_3PO_4).
- Decon Solution B - A solution containing 10% Calcium Hypochlorite ($Ca(ClO)_2$).
- Decon Solution C - A solution containing 5% Trisodium Phosphate (Na_3PO_4). This solution can also be used as a general purpose rinse.
- Decon Solution D - A dilute solution of Hydrochloric Acid (HCl).

All diving helmets, jocking harnesses, weight belts, and umbilicals must be thoroughly scrubbed, deconned, and rinsed after each operational day.

Insofar as possible, measures should be taken to prevent contamination of sampling and monitoring equipment. Sampling devices become contaminated, but monitoring instruments, unless they are splashed, usually do not. Once contaminated, instruments are difficult to clean without damaging them. Any delicate instrument which cannot be decontaminated easily should be protected while it is being used. It should be bagged, and the bag taped and secured around the instrument. Openings are made in the bag for sample intake.

The following are specific areas of concern in decontamination operations:

1. Sampling devices

   Sampling devices require special cleaning. The EPA Regional Laboratories can provide information on proper decontamination methods.

2. Tools

   Wooden tools are difficult to decontaminate because they absorb chemicals. They should be kept on site and handled only by protected workers. At the end of the response, wooden tools should be discarded. For decontaminating other tools, Region Laboratories should be consulted.

3. Respirators

   Certain parts of contaminated respirators, such as the harness assembly and leather or cloth components, are difficult to decontaminate. If grossly contaminated, they may have to be discarded. Rubber components can be soaked in soap and water and scrubbed with a brush. Regulators must be maintained according to manufacturer's recommendatons. Persons responsible for decontaminating respirators should be thoroughly trained in respirator maintenance.

4. Heavy Equipment

Bulldozers, trucks, back-hoes, bulking chambers, and other heavy equipment are difficult to decontaminate. The method generally used is to wash them with water under high pressure and/or to scrub accessible parts with detergent/water solution under pressure, if possible. In some cases, shovels, scoops, and lifts have been sand blasted or steam cleaned. Particular care must be given to those components in direct contact with contaminants such as tires and scoops. Swipe tests should be utilized to measure effectiveness.

5. Sanitizing of Personnel Protective Equipment

Respirators, reusable protective clothing, and other personal articles not only must be decontaminated before being reused, but also sanitized. The inside of masks and clothing becomes soiled due to exhalation, body oils, and perspiration. The manufacturer's instructions should be used to sanitize the respirator mask, If practical, protective clothing should be machine washed after a thorough decontamination; otherwise it must be cleaned by hand.

6. Persistent Contamination

In some instances, clothing and equipment will become contaminated with substances that cannot be removed by normal decontamination procedures. A solvent may be used to remove such contamination from equipment if it does not destroy or degrade the protective material. If persistent contamination is expected, disposable garments should be used. Testing for persistent contaminaton of protective clothing and appropriate decontamination must be done by qualified laboratory personnel.

7. Disposal of Contaminated Materials

All materials and equipment used for decontamination must be disposed of properly. Clothing, tools, buckets, brushes, and all other equipment that is contaminated must be secured in drums or other containers and labeled. Clothing not completely decontaminated on-site should be secured in plastic bags before being removed from the site.

Contaminated wash and rinse solutions should be contained by using step-in-containers (for example, child's wading pool) to hold spent solutions. Another containment method is to dig a trench about 4 inches deep and line it with plastic. In both cases the spent solutions are transferred to drums, which are labeled and disposed of with other substances on site.

Appendix F, Annex 1, 2, and 3 describe basic decontamination procedures for a worker wearing Level LA, B, or C protection. The basic decontamination lines (Situation 1), consisting of approximately 19 stations, are almost identical except for changes necessitated by different protective clothing or respirators. For each annex, three specific situations are described in which the basic (or full decontamination) procedure is changed to take into account differences in the extent of contaminaiton, the accompanying changes in equipment worn, and other factors. The situations illustrate decontamination setups based on known or assumed conditions at an incident. Many other variations are possible.

Annex 4 describes a minimum layout for personnel decontamination. The number of individual stations ahve been reduced. Although the decontamination equipment and amount of space required is less than needed in the procedures previously described, there is also a much higher probability of cross-contamination.

SECTION 25

SOURCES OF INFORMATION AND RESPONSE ASSISTANCE

In a hazardous spill situation, the OSC or MSO must swiftly assess site conditions, not only prior to allowing diving personnel to enter a contaminated water environment, but also to whatever hazards his/her surface response workers face.

Many sources of information and organizations can provide response personnel with technical data and physical assistance regarding both the hazards associated with an incident and methods of dealing with them. It is necessary to be aware of these resources and to know how to use them.

The information, which may include data on sites, topography, meteorology, physical/chemical properties of the material, applicable treatment methods, and available cleanup resources, can be provided by various agencies, maps, reference books, and manuals. It is advisable to get data from at least two sources and to use the latest edition of any reference, especially when searching for hygienic standards or toxicological data.

Access to on-line computer files may be possible at the site if a telephone, portable terminal, and 120-volt outlet are available. Aerial photographs can also provide useful information when interpreted properly.

NOAA Hazardous Materials Response Project

NOAA's Hazardous Materials Response Project (HAZMAT) is a member of one of the groups of special forces available upon request to Federal On-Scene Coordinators (OSC) for response to actual or potential releases of pollutants, such as oil and hazardous materials, as well as for contingency planning. When responding to a potentially hazardous spill, HAZMAT relies upon four main groups for quick reliable information. The functions of these groups are outlined below.

Trajectory Analysis/Physical Oceanography
Dr. Jerry Galt
NOAA/OMPA
7600 Sand Point Way, N.E.
Seattle, Washington 98115
(206)527-6317

The trajectory analysis/physical oceanography group is concerned with the movement and spreading of pollutants in the marine environment. Their goal is to define trajectories for both waterborne and airborne contaminants in a timely manner. In order to achieve this objective, Dr. Galt has developed a sophisticated computer model. Field equipment such as cameras, portable darkrooms, and current measuring equipment help to verify their predictions in the field.

Research Planning Institute

The environmental sensitivity analysis group is concerned with environmental resources at risk from a pollutant discharge. Advance mapping of coastal areas develop reference maps available for immediate referral in the event of a spill. The Research Planning Institute has a staff of professionals in the areas of chemistry, geology, biology, marine ecology, and geochemistry which lends its support to the development of these valuable references.

Environmental Sensitivity Analysis
Dr. Erich Gundlach
Dr. Jacqui Michel
Research Planning Institute
925 Gervais Street
Columbia, SC 29201
(803)256-7322

Chemical Support and Safety

The Chemical Support and Safety group works closely together to define the hazard and make appropriate safety recommendations. The chemistry/safety problem is best defined by consulting a number of reference sources. HAZMAT routinely uses the following references along with a computer-based information system known as the Chemical Information System (CIS).

Chemical Support Safety and Health
Chemistry: Dr. Ed Overton
Center for Bio-Organic Studies
University of New Orleans
New Orleans, LA 70122
(504)283-6640)

Safety and Health:
David Kummerlowe
NOAA/OMPA
7600 Sand Point Way, N.E.
Seattle, Washington 98115
(206)527-6326

Center for Disease Control

The Center for Disease Control provides detailed technical assistance in human toxicology and in the evaluation and monitoring of health risks. CDC has experts located in all coastal regions to assist with safety-related and human exposure problems.

National Center for Disease Control
Dr. Georgia Jones
CDC-Center of Environmental Health
1600 Clifton Road, N.E.
Atlanta, GA 30333

Appendix F contains a listing of basic references, On-Line Computer Systems, remote sensing and map interpretation information, and a list of technical assistance organizations.

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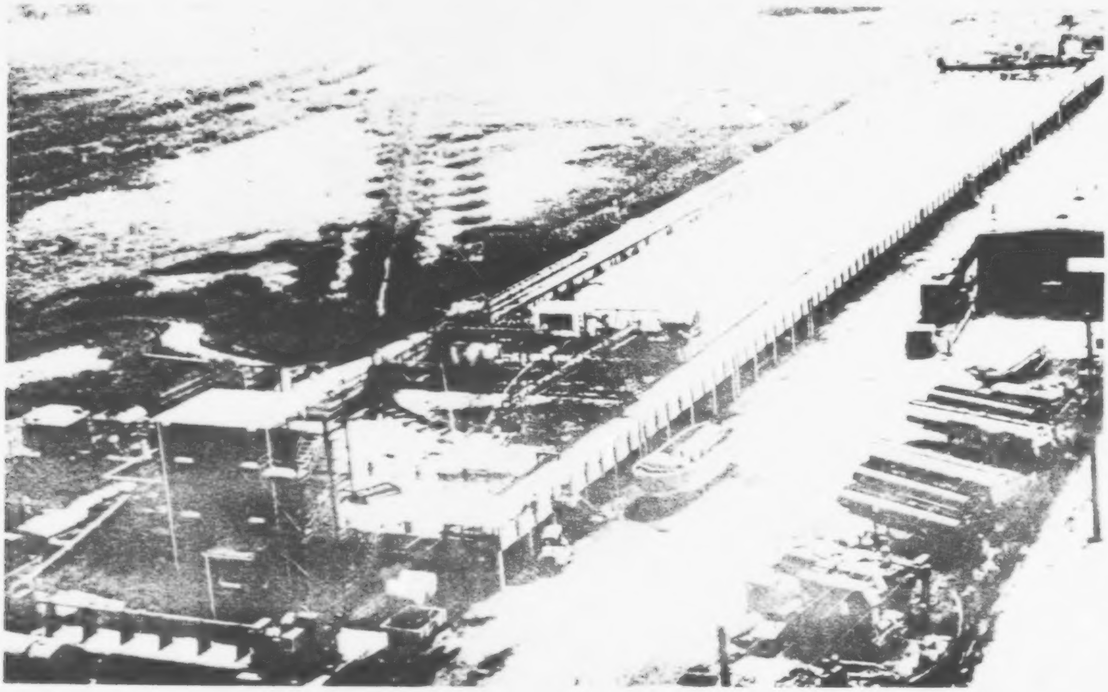
APPENDIX A

OHMSETT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY



The U.S. Environmental Protection Agency operates the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey. This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control and clean-up of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203 metres (667 feet) long by 20 metres (65 feet) wide and with a water depth of 2.4 metres (8 feet). The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a horizontal force up to 151 kilonewtons (34,000 pounds) while towing floating equipment at speeds to 3.3 metres/second (6.5 knots) for at least 40 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of the water several metres ahead of the device being tested, so that reproducible thicknesses and widths of the test slicks can be achieved with minimum interference by wind.

The prinicipal systems of the tank include a wave generator, a beach, and a filter system. The wave generator and absorber beach can produce regular waves to 0.6 metre (2 feet) high and to 45 metres (147 feet) long, as well as a series of 0.7 metres (2.3 feet) high reflecting, complex waves meant to simulate the water surface of a harbor. The tank water is clarified by recirculation through a 410 cubic metre/hour (1800 gallon per minute) diatomaceous earth filter system to permit full use of a sophisticated underwater photography and video imagery system and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in oil barrier which is used to skim oil to the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume of 9800 cubic metres (2.6 millon gallons) is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests.

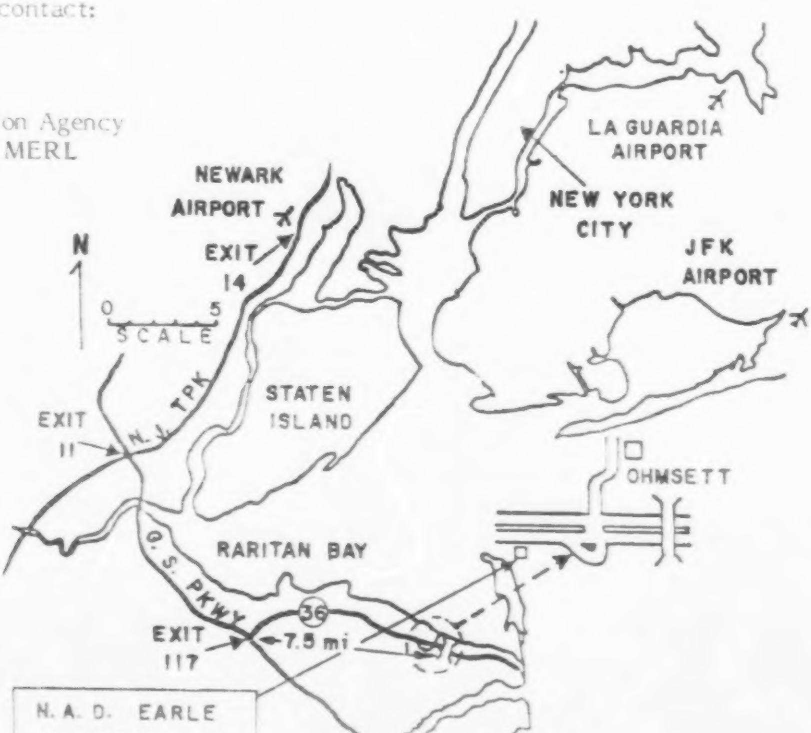
Testing at the facility is served from a 650 square metres (7,000 square feet) building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of eighteen multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology and overall project direction.

For additional information, contact:

Richard A. Griffiths
OHMSETT Project Officer
U.S. Environmental Protection Agency
Research and Development, MERL
Edison, New Jersey 08817

Telephone: 201-321-6629.



APPENDIX B

AIR MONITORING AND SURVEY INSTRUMENTS

I. INTRODUCTION

Response to an environmental incident requires careful preparation and prompt action to reduce the hazards. Concurrently, the health and safety of response personnel and the general public must be protected. Air monitoring and survey instruments provide information to determine how these requirements are being met. The purpose of this part is to:

- List field instruments useful for on-site work.
- Describe the operating theories and principles of these instruments.
- Illustrate the proper interpretation and limitations of the data obtained.

Used correctly, these instruments provide data that help response personnel to determine:

- Potential or real effects on the environment.
- Immediate and long-term risks to public health, including the health of response workers.
- Appropriate personnel protection and respiratory equipment to be used on-site.
- Actions to mitigate the hazard(s) safely and effectively.

II. CHARACTERISTICS OF FIELD INSTRUMENTS

To perform effectively in the field, air monitoring instruments must be:

- Portable
- Able to generate reliable and useful results
- Sensitive and selective
- Inherently safe

All of these traits may or may not be present in any one instrument.

A. Portability

A prime consideration that determines the usefulness of a field instrument is portability. Transporation shock resulting from the movement from one place to another, together with unintentional abuse, ranks high in shortening the usable life of an instrument. To reduce this trauma, instruments should be selected that have reinforced shells or frames, shock-mounted electronic packages, or padded containers for shipment.

Exposure to the elements and the test atmosphere itself is of concern for those instruments repeatedly used in adverse conditions or as long-term monitors. Anodized or coated finishes, weather-resistant packaging and remote sensing are effective in reducing downtime and increasing portability.

In short, a portable unit should possess ease in mobility, the ability to withstand the rigors of use, quick assembly, and short check out and calibration time.

B. Reliable and Useful Results

Response time, the interval between an instrument "sensing" a contaminant and generating data, is important to producing reliable and useful results in the field. Response time depends on: test(s) to be performed, dead time between sample periods (the time for analysis, data generation, and data display), and the sensitivity of the instrument. Response time establishes the pace of the overall survey and the individual tests.

Another consideration is that the instrument must give results that are immediately useful. Instruments should be direct reading, with little or no need to interpolate, integrate, or compile large amounts of data.

C. Sensitivity and Selectivity

A third requirement of a good field instrument is the ability to sample and analyze very low contaminant levels, and to discern among contaminants exhibiting similar characteristics.

Sensitivity defines the lowest concentration an instrument can accurately and repeatedly analyze. In the strictest sense, it is a function of the detecting ability of the instrument, and does not address the electronic amplifier, if the unit has one. The operating range establishes the upper and lower use limits of the instrument. It encompasses the sensitivity limit at its lower end and the overload point at its upper.

Selectivity establishes what contaminants will elicit a response on the instrument. Additionally, selectivity mandates which, if any, interferences may produce a similar response. Selectivity and sensitivity must be reviewed and interpreted together. Many devices have high selectivity but widely varying sensitivities for a given family of chemicals, for example aromatics, aliphatics, and amines.

Amplification, often used synonymously (and incorrectly) with sensitivity, deals with an electronic amplifier's ability to increase very small electrical signals emanating from the detector. This capacity may be fixed or variable. However, changing the amplification of the detector does not change its sensitivity. For optimum field usefulness, an instrument should possess high sensitivity, wide range, high selectivity, and the ability to vary the amplification of detector signals.

D. Inherent Safety

One of the greatest concerns when using an electrically operated instrument is its potential to ignite a flammable atmosphere. The sources of this ignition could be: an arc generated by the power source itself or the associated electronics, and/or a flame or heat source inherent in the instrument and necessary for its proper functioning.

Several features can be added to an instrument to eliminate ignition sources while allowing the instrument to perform as designed.

1. Controls

Three methods exist to prevent a potential ignition source from igniting a flammable atmosphere:

- Encase the ignition source in a rigidly built container. "Explosion-proof" instruments allow the flammable atmosphere to enter. If and when an arc is generated, the ensuing explosion is contained within the specially designed and built enclosure. Within it, any flames or hot gases are cooled prior to exiting into the ambient flammable atmosphere so that the explosion does not spread into the environment.

- Reduce the potential for arcing among components by encasing them in a solid insulating material. Also, reducing the instrument's operational current and voltage below the energy level necessary for ignition of the flammable atmosphere provides equal protection. An "intrinsically safe" device, as defined by the National Electrical Code, is incapable "of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration. Abnormal conditions shall include accidental damage to any...wiring, failure of electrical components, application of over-voltage, adjustment and maintenance operations and other similar conditions."

- Buffer the arcing or flame-producing device from the flammable atmosphere with an inert gas. In a pressurized or "purged" system, a steady stream of, for example, nitrogen or helium is passed by the potential arcing device, keeping the flammable atmosphere from the ignition source. This type of control, however, does not satisfactorily control analytical devices that use a flame or heat for analysis.

2. Hazardous Atmospheres

Depending upon the response worker's background, the term "hazardous atmosphere" conjures up situations ranging from toxic air contaminants to flammable atmsopheres. For our purposes, an atmosphere is hazardous if it meets the following criteria:

- It is a mixture of any flammable material in air (see Class and Group below) whose composition is within this material's flammable range.
- A critical volume of the mixture is sufficiently heated by an outside ignition source.
- The resulting exothermic reaction propagates the flame beyond where it started.

Hazardous atmospheres can be produced by one of three general types of materials:

- Flammable gases/vapors
- Combustible dusts
- Ignitable fibers

Whereas the flammable material may define the hazard associated with a given product, the occurence of release, (how often the material generates a hazardous atmosphere) dictates the risk. Two types of releases are associated with hazardous atmospheres:

- Continuous: Those existing continuously in an open unconfined area during normal operating conditions.
- Confined: Those existing in closed containers, systems or piping, where only ruptures, leaks, or other failures result in a hazardous atmosphere outside the closed system.

There are six possible environments in which a hazardous atmosphere can be generated. However not every type of control will prevent an ignition in every environment. To adequately describe the characteristics of those environments and what controls can be used, the National Electrical Code defines each characteristic:

- Class is a category describing the type of flammable material that produces the hazardous atmosphere:

  -- Class I is flammable vapors and gases, such as gasoline, hydrogen. Class I is further divided into groups A,B,C,and D on the basis of similar flammability characteristics (Table 1-1).

  -- Class II consists of combustible dusts like coal or grain and is divided into groups E,F, and G.

  -- Class III is ignitable fibers such as produced by cotton milling.

- Division is the term describing the "location" of generation and release of the flammable material.
  - Division 1 is a location where the generation and release are continuous, intermittent, or periodic into an open, unconfined area under normal conditions.
  - Division 2 is a location where the generation and release are in closed systems or containers and only from ruptures, leaks or other failures.

Using this system, a hazardous atmosphere can be routinely and adequately defined. As an example, a spray-painting operation using acetone carrier would be classified as a Class I, Division 1, Group D environment. Additionally, an abandoned waste site containing intact closed drums of methyl ethyl ketone, toluene, and xylene would be considered a Class I; Division 2, Group D environment. Once the containers begin to leak and produce a hazardous atmosphere, the environment changes to Class I, Division 1, Group D.

III. CERTIFICATION PROTOCOLS

A given ignition control device is selected for a specific Class, Division, and Group, per the manufacturer's specifications and the end user's requirement. There are no guarantees however, that the device will prevent ignition of a hazardous atmosphere, unless it has been tested. The test should include the worst case situation(s) this device could encounter in the field.

A. Primary Certification Groups

Several engineering, insurance, and safety industries standardized test protocols, established inclusive definitions, and developed codes for testing electrical devices used in hazardous locations. The National Fire Protection Association (NFPA), a forerunner in this endeavor, created minimum standards in its National Electrical Code (NEC), published every 3 years.

This code spells out among other things:

- Types of controls acceptable for use in hazardous atmospheres, that is, explosion-proof, intrinsically safe, or purged.
- Types of areas in which flammable atmospheres can be generated-Division 1 or Division 2.
- Types of materials that generate these atmospheres, that is, Class I, II, or III and their associated groups.

TABLE B-1

CLASS I CHEMICALS BY GROUPS

Group A Atmospheres

- Acetylene

Group B Atmospheres

- Butadiene
- Ethylene oxide
- Hydrogen
- Manufactured gases containing more than 30% hydrogen (by volume)
- Propylene oxide

Group C Atmospheres

- Acetaldehyde
- Crotonaldehyde
- Cyclopropane
- Diethyl ether
- Ethylene
- Unsymmetrical dimethyl hydrazine (UDMH, 1-, 1-dimethyl hydrazine)

Group D Atmospheres

- Acetone
- Acrylonitrile
- Ammonia
- Benzene
- Butane
- 1-Butanol (butyl alcohol)
- 2-Butanol (secondary butyl alcohol)
- 2-Butyl acetate
- n-Butyl acetate
- Isobutyl acetate
- Ethane
- Ethanol (ethyl alcohol)
- Ethyl acetate
- Ethylene dichloride
- Gasoline
- Heptanes
- Hexanes
- Isoprene
- Methane (natural gas)
- Methanol (methyl alcohol)
- 3-Methyl-1-butanol (isoamyl alcohol)
- Methyl ethyl ketone
- Methyl isobutyl ketone
- 2-Methyl-1-propanol (isobutyl alcohol)
- 2-Methyl-2-propanol (tertiary butyl alcohol)
- Octanes
- Petroleum naphtha[1]
- Pentanes
- 1-Pentanol (amyl alcohol)
- Propane
- 1-Propanol(propyl alcocol)
- 2-Propanol (isopropyl alcohol)
- Propylene
- Styrene
- Toluene
- Vinyl acetate
- Vinyl chloride
- Xylenes

Source: *National Electrical Code*, Vol. 70, Table 500-2. National Fire Protection Association, 470 Atlantic Ave., Boston MA 02210 (1975).

[1] A saturated hydrocarbon mixture boiling in the range 20°-135°C (68°-275°F). Also known by the synonyms benzine, ligroin, petroleum ether, or naphtha.

Other national groups such as Underwriters Laboratories (UL), Factory Mutual (FM), and the American National Standards Institute (ANSI), together with NFPA, developed test protocols for certifying explosion-proof, intrinsically safe, or purged devices to meet minimum standards of acceptance.

An electrical device certified under one of these test protocols carries a permanently affixed plate showing the logo of the laboratory granting certification and the Class(es), Division(s), and Group(s) it was tested against.

Certification means that if a device is certified as explosion-proof, intrinsically safe, or purged for a given Class, Division, and Group, and is used, maintained, and serviced according to the manufacturer's instructions, it will not contribute to ignition.

Any manufacturer wishing to have an electrical device certified by FM or UL must submit a prototype for testing. If the unit passes, it is certified as submitted. However the manufacturer agrees to allow the testing laboratory to randomly check the manufacturing plant at any time, as well as any marketed units. Furthermore, any change in the unit requires the manufacturer to notify the test laboratory, which can continue the certification or withdraw it until the modified unit can be retested.

B. Selection of Certified Devices

On a site generating a hazardous atmosphere (or having the potential to), the use of certified equipment gives response personnel a margin of safety. The following points will assist in selection of equipment that will not contribute to ignition of a hazardous atmosphere:

- In an area designated Division 1, there is a greater probability of generating a hazardous atmosphere than in Division 2. Therefore, the test protocols for Division 1 certification are more stringent than those for Division 2. Thus a device approved for Division 1 is also permitted for use in Division 2, but not vice versa.

- There are so many Groups, Classes, and Divisions that it is impossible to certify an all-inclusive instrument. Therefore, select a certified device based on the chemicals and conditions most likely to be encountered. For example a device certified for a Class II, Division 1, Group E (combustible metal dust) would offer little protection around a flammable vapor or gas.

The use of a certified instrument in an environment other than what it has been certified for provides no better protection than use of a noncertified device.

An instrument certified as intrinsically safe for a given Group in a Class I, Division 1 area carries "non incendiary" certification for Division 2.

An intrinsically safe certification contains requirements for redundant systems and provides protection under normal and abnormal or faulty conditions, while a non incendiary certification does not. Instead, ignition protection is offered only when the certified device is used according to the manufacturer's instructions and under the environmental conditions expected in a Division 2 area.

This certification may also be awarded to instruments that are incapable of releasing sufficient electrical or thermal energy to ignite flammable gases or vapors of a Division 2, Class I location (Figure 1-1).

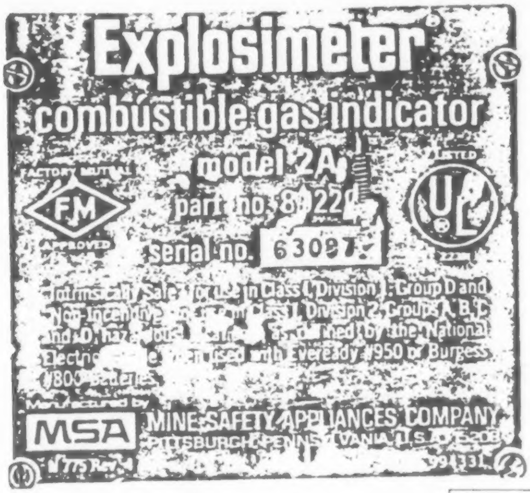

Explosimeter
combustible gas indicator
model 2A
Factory Mutual
FM
Approved
part no.
serial no. 63097
Listed
UL
Class I, Division 1, Group D and
Class I, Division 2, Groups A, B, C
and D hazardous
by the National
used with Eveready #950 or Burgess
#800 Batteries
Manufactured by
MSA
MINE SAFETY APPLIANCES COMPANY
PITTSBURGH, PENNSYLVANIA U.S.A.
94331

FIGURE B.1

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EXAMPLE OF INSTRUMENT CERTIFICATION

A unit may be certified either by UL, FM or both. Both laboratories follow test protocols established by NFPA and ANSI. Therefore one certification is no better or worse than the other. The important consideration is that the device is approved for the Class(es), Division(s) and Group(s) it will be used in.

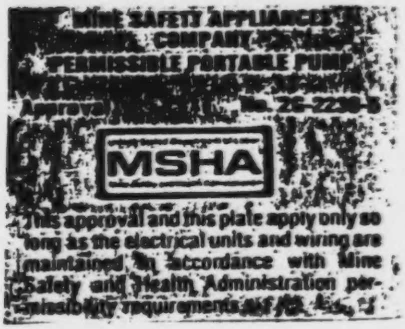
The mention of FM or UL in the manufacturer's equipment literature does not guarantee certification. All certified devices that are used in hazardous (flammable) locations must be marked to show Class, Division, and Group, per NEC Table 500-2(b).

C. Other Certifications

Other organizations such as the Mine Safety and Health Administration (MSHA), Canadian Standards Association (CSA), National Electrical Manufacturers Association (NEMA), and the U.S. Coast Guard (USCG) have developed their own testing and certification schemes for electrical devices in hazardous locations common to their jurisdiction.

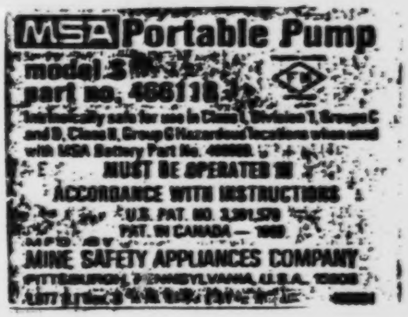
MSHA tests and certifies electrical equipment to be used in hazardous atmospheres associated with underground mining. These atmospheres usually contain methane gas and coal dust; hence the tests and certification are specific to those two contaminants.

Often the same testing equipment is used in the mines as well as above ground and therefore carrying both certifications: MSHA and FM or UL (Figures 1-2 and 1-3). Note that FM certifies the pump for Class II, Group G, grains, dusts, and flours, which are not found underground.



MINE SAFETY APPLIANCES
COMPANY
PERMISSIBLE PORTABLE PUMP
[illegible]
Approval [illegible] No. 2G-2230-[illegible]
MSHA
This approval and this plate apply only so long as the electrical units and wiring are maintained in accordance with Mine Safety and Health Administration permissibility requirements [illegible]

FIGURE B.2



MSA Portable Pump
model S[illegible]
part no. 466118 [illegible]
Intrinsically safe for use in Class I, Division 1, Groups C and D, Class II, Group G Hazardous locations when used with MSA Battery Part No. [illegible]
MUST BE OPERATED IN ACCORDANCE WITH INSTRUCTIONS
U.S. PAT. NO. [illegible]
PAT. IN CANADA — [illegible]
MFD. BY
MINE SAFETY APPLIANCES COMPANY
PITTSBURGH, PENNSYLVANIA, U.S.A. [illegible]

FIGURE B.3

A device with only an MSHA certification does not offer the same protection in hazardous atmospheres generated from other materials in the same Class and Group as methane (Class I, Group D) or coal dust (Class II, Group F). Only when the device is approved by MSHA and UL and/or FM for a specific Class and Group does the certification offer the same protection for all members of that Class and Group.

IV. FIELD INSTRUMENTS

A. Introduction

Several field instruments in use today analyze ambient air for:

- Percentage of the lower flammability limit of a vapor or gas in air.
- Concentration of oxygen.
- Concentration of toxic vapors/gases.

There are no formalized schemes separating one type of instrument from another. However, to facilitate training, the instruments can be divided into two categories - general survey and specific survey - based on the type of sampling performed.

B. General Survey Instruments

General survey instruments are devices capable of measuring a number of compounds or materials via a specific test. All must be calibrated and given their pre-operational checks in a noncontaminated atmosphere. General survey instruments include the combustible gas indicator, ultraviolet photoionization detector, gas chromatograph, and infrared spectrophotometer. They provide information to the trained operator on the next "step" to take, be it additional sampling, monitoring, or evacuation of personnel from the site.

1. Combustible Gas Indicators (CGI's)

The Combustible Gas Indicator (CGI) is one of the first instruments to be used to survey a site. It measures the concentration of a flammable vapor or gas in air, indicating the results as a percent of the Lower Explosive Limit (LEL) of the calibration gas or vapor. Depending on the manufacturer and model, a meter needle indicating 1.0 or 100% reveals that the test atmosphere contains a concentration of flammable material in air at the LEL. This environment could ignite or explode in the presence of an ignition source. A meter reading of 0.5 or 50% indicates that the air contains approximately 1/2 of the LEL.

In addition, the needle rapidly can climb to 1.0 (100%), pass it, and then fall to zero, or below. This does not indicate that the CGI is malfunctioning or that the atmosphere contains no vapors. It indicates that the concentration of vapor- or gas-in-air exceeds the Upper Explosive Limit (UEL) of the calibration gas. Such a situation calls for rapid evacuation of the area because this atmosphere can quickly become highly flammable.

a. Theory

Most combustible gas indicators operate on the "hot wire" principle. In these detectors, a filament is heated by the burning of the vapor or gas. The heat increases the electrical resistance of the wire thereby decreasing the current passing through it. The current in this filament is compared to that of a reference filament, and the percent of the LEL (for the calibration gas) is displayed.

b. Limitations

As with any instrument based on an electrochemical reaction, all CGI's have several limitations:

- The reaction is temperature dependent. Therefore, the measurement is only as accurate as the incremental difference between calibration and ambient (sampling) temperatures.
- Sensitivity is a function of physical and chemical properties of the calibration gas versus those of the unknown contaminant.

The hot wire CGI suffers from these additional drawbacks:

- For accurate measurements, the oxygen content must be at the concentration at which the manufacturer calibrated the unit.
- Several chemicals can poison or shorten the life of the filament, among them tetraethyl lead, silicones, and halides.

2. Ultraviolet (UV) Photoionization Detector

a. Theory

The light from the sun when passed through a prism is dispersed into the many colors that make up the white light spectrum. The hues of colors from the deep reds through the deep purples are a relatively small segment in the overall electromagnetic (e-m) spectrum. The e-m spectrum covers long wavelengths such as radio waves through the ultrashort wave gamma radiation (Figure 1-4). As the wavelengths decrease in size (higher frequencies), the wave energy increases. This relationship between energy and frequency is based upon Planck's equation.

All atoms and molecules are composed of particles: electrons, protons, and neutrons. Electrons, negatively charged particles, rotate in orbit around the nucleus, the dense inner core. The nucleus consists of an equal number of protons (positively charged particles) as electrons found in the orbital cloud. The interaction of the oppositely charged particles and the laws of quantum mechanics keep the electrons in orbits outside the nucleus.

The energy required to remove the outermost electron from the molecule is called the ionization potential (IP) and is specific for any compound or atomic species. IP is measured in electron volts (eV). High frequency radiation (ultraviolet and above) is capable of causing ionization and is hence called ionizing radiation.

When a photon of ultraviolet radiation strikes a chemical compound, it ionizes the molecule if the energy of the radiation is equal to or greater than the IP of the compound. Since ions are capable of conducting an electrical current, they may be collected on a charged plate. The measured current will be directly proportional to the number of ionized molecules.

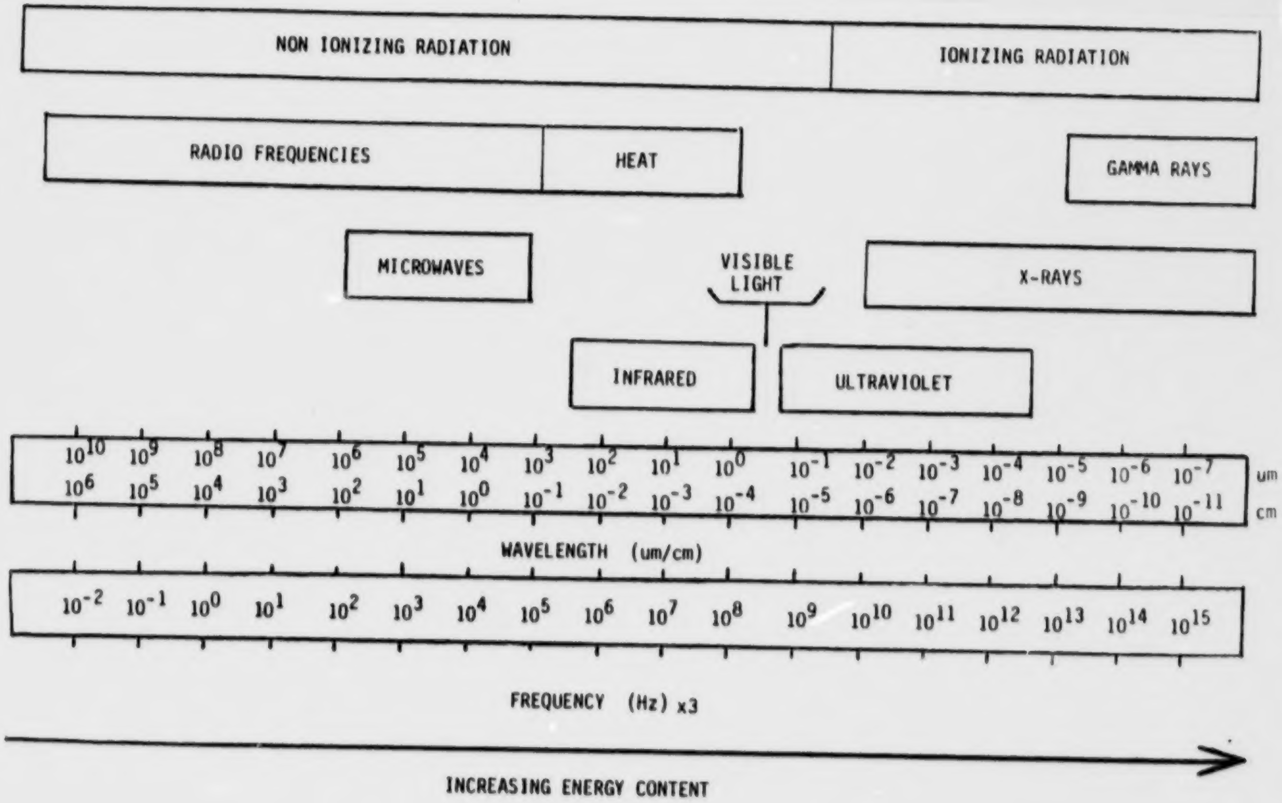

NON IONIZING RADIATION
IONIZING RADIATION
RADIO FREQUENCIES
HEAT
GAMMA RAYS
MICROWAVES
VISIBLE LIGHT
X-RAYS
INFRARED
ULTRAVIOLET
10^{10} 10^{9} 10^{8} 10^{7} 10^{6} 10^{5} 10^{4} 10^{3} 10^{2} 10^{1} 10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} um
10^{6} 10^{5} 10^{4} 10^{3} 10^{2} 10^{1} 10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} cm
WAVELENGTH (um/cm)
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15}
FREQUENCY (Hz) x3
INCREASING ENERGY CONTENT

FIGURE B-4
THE ELECTROMAGNETIC SPECTRUM

b. Practical Considerations

The HNU is typical of field photoionization units now available. It consists of two parts connected via a signal-power cord (Figure 1-5):

- A probe consisting of the UV light source, pump, ionization chamber, and a preamplifier.
- A readout unit consisting of amplifier and electrical circuits, a display meter, and battery pack.

An electrical pump pulls the air stream past a 10.2-eV UV source. The radiation produces an ion pair for each molecule of contaminant ionized. The free electrons produce a current directly proportional to the number of ions produced. The current is amplified, detected, and displayed on the meter.

Normally, the HNU is used with a 10.2-eV source that ionizes many of the common air contaminants. A probe using a 9.5-eV source and another using a 11.7-eV source are also available.

The 11.7-eV source should be used to initially investigate an area. However, it requires constant maintenance and frequent replacement. Thus, except in rare situations, the 10.2-eV lamp/probe should be used. It offers relatively high radiation levels without time-consuming maintenance and costly equipment.

Parallel use of the 9.5-eV and 10.2-eV lamp/probe sets allows semiquantitative analysis. Assume a mixture consisting of two materials, one with an IP of 9.2-eV, the other with 10.2-eV. Both will be measured by the 10.2-eV lamp/probe, but only the 9.2-eV contaminant on the 9.5-eV lamp/probe. Substracting the second reading from the first gives the concentration of the 10.2-eV contaminant.

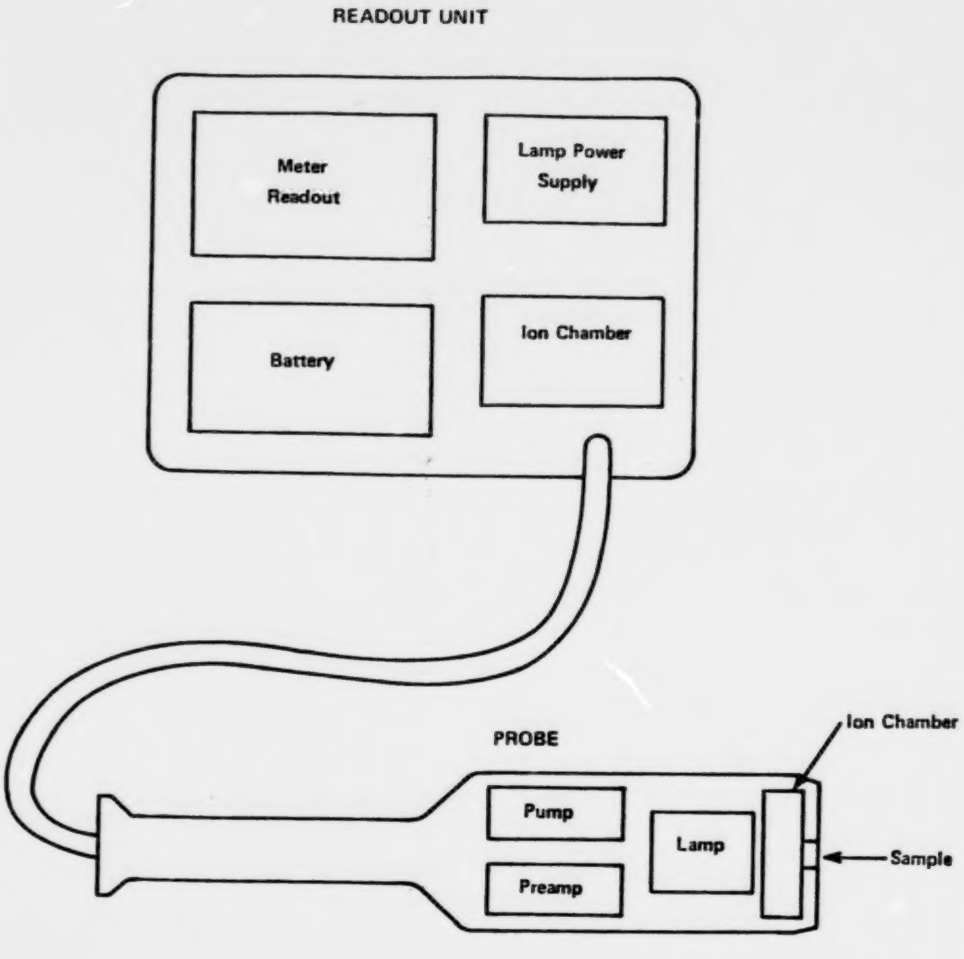


FIGURE B-5
PORTABLE PHOTOIONIZATION ANALYZER

c. Limitations

Although the HNU photoionization unit is an excellent instrument for survey, there are very important limitations.

- The response to a gas or vapor may radically change when the gas or vapor is mixed with other materials. As an example, a HNU calibrated to ammonia and analyzing an atmosphere containing 100 ppm would indicate 100 on the meter. Likewise, a unit calibrated to benzene would record 100 in an atmosphere containing 100 ppm concentration. However, in an atmosphere containing 100 ppm of each, the unit could indicate considerably less or more than 200 ppm, depending on how it was calibrated.
- Electromagnetic interference from pulsed DC or AC power lines, transformers, and high voltage equipment may produce an error as will nearby transmissions.
- The lamp window must be periodically cleaned to ensure ionization of the air containments.
- Although the HNU measures concentrations from 1 ppm, the response (to benzene) is linear from 0 to about 600 ppm. This means the HNU reads a true concentration of benzene only between 0 and 600. Greater concentrations may be "read" at a higher or lower level than the true value.

d. Use at sites

The HNU is a good choice to determine the proper lever of protection in evaluationg a hazardous waste site oe spill. The need to properly interpret the HNU's data cannot be overemphasized. Equally important is the need to understand the limitations of this instrument.

One particularly important limitation for on-site use is how the HNU responds toward mixtures containing chemicals with very similar IP's. In a typical industrial plant, usually only one gas or vapor must be measured in a specific setting. This is relatively simple for the HNU, and interferences and complications rarely exist. As a rule, the HNU is more sensitive to complex compounds and less sensitive to simpler ones. In order of decreasing sensitivity, measured on a scale of 1 to 10, the HNU respondes to:

- Aromatics (e.g., benzene, toluene, xylene) and aliphatic amine hydrocarbons: 10
- Unsaturated chlorinated hydrocarbons (e.g., trichloroethylene, dichloroethylene): 5-9
- Unsaturated hydrocarbons (e.g., propylene): 3-5
- Paraffinic hydrocarbons with 5 to 7 carbons (e.g., hexane, heptane): 1-3
- Ammonia and paraffinic hydrocarbons with 1 to 4 carbons (e.g., ethane, propane): less than 1.

To compensate for this lack of sensitivity, the HNU incorporates a span pot (potentiometer), which varies the gain on the amplifier. In the full clockwise (CW) position at level 9.8, the HNU indicates the approximate air concentration of all chemicals with a sensitivity of 10 for example, aromatic hydrocarbons. In full counterclockwise (CCW) position at level 0, it indicates the approximate concentration of ammonia or paraffinic hydrocarbons. With the span pot positioned at any intermediate point, HNU indicates the approximate air concentration of the chemical whose sensitivity corresponds to that level.

When the span pot is set at 0 (fully CCW) and the function switch to the 0-20 range, the scale on the meter face reads 0-2 ppm. This expansion, which is valid only for materials that have a relative sensitivity of 10, allows measurements in the parts-per-billion range (ppb).

In most circumstances, using the HNU on the lowest setting (span pot 9.8, function switch 0-20) provides adequate data to select the proper protection (Levels A, B, C, D) for on-site workers. Unfortunately, several chemicals- for example, acrolein-exhibit medium to low sensitivity (0-5), while their toxicological effects place their threshold limit value (TLV) at a very low level. If these chemicals are indicated by the HNU (on its lowest setting) response could select too low a protection level. Consider this scenario:

> The air in an unknown hazardous environment must be sampled. Response personnel survey the site with an HNU, which indicates 2.0 ppm (instrument set to highest sensitivity). Level C protection may be worn based upon the instrument's data. Later, the air contaminant is found to be acrolein with a TLV of 0.1 ppm (100 ppb) and an immediate dangerous to life or health (IDLH) level of 5 ppm.

Thus total reliance to the HNU data without regard for the chemical makeup of the sample can be a problem.

3. Flame Ionization Detection (FID)

a. Theory

The FID uses ionization as the detection method, much the same as in the HNU, except that the ionization is caused by a hydrogen flame, rather than by a UV light. This flame has sufficient energy to ionize any organic species with an IP of 15.4 or less. The ions are then passed between two charged plates. The conductivity change is measured, the current charge is displayed on an measured, the current charge is displayed on an external meter, and read in parts per million.

b. Century Systems Organic Vapor Analyzer (OVA)

The Century Systems Organic Vapor Analyzer (OVA) is a portable FID unit. This package consists of two major parts,

- A 9-pound package containing the sampling pump, battery pack, support electronics, flame ionization detector, hydrogen gas cylinder, and an optional gas chromatography (GC) column.

- A hand-held meter/sampling probe assembly.

The OVA can operate in two modes:

- Survey mode: A sample of ambient air is routed through the OVA into the detector, allowing all organic species to be ionized and detected at the same time. Based on the sensitivity of the instrument to various compounds, a concentration is displayed on the meter. The OVA is calibrated to methane.

- Gas chromatography mode: Gas chromatography (GC) is a technique for separating volatile substances by percolating a gas stream over a stationary phase. The components to be separated are carried through a column packed with an inert solid. A liquid is spread as a thin film over this solid and is the basis for separation. The different components of the sample migrate through the column at different rates. The component bands then leave the column and are measured by the detector. In this fashion, individual components of the ambient atmosphere may be analyzed. More complete instructions on the use of the Century Systems OVA can be found in the owner's manual.

c. Limitations

As with HNU Photoionizer, the OVA responds differently to different compounds. Below is a list, provided by the manufacturer of the relative sensitivities of the OVA to some common organic compounds. Since the instrument is factory calibrated to methane, all relative responses are given in percent, with methane at 100.

Compound	Relative Response
Methane	100
Ethane	90
Propane	64
n-Butane	61
n-Pentane	100
Ethylene	85
Acetylene	200
Benzene	150
Toluene	120
Acetone	100
Methyl ethyl ketone	80
Methyl isobutyl ketone	100
Methanol	15
Ethanol	25
Isopropyl alcohol	65
Carbon tetrachloride	10
Chloroform	70
Trichloroethylene	72
Vinyl chloride	35

4. Infrared Spectrophotomer

a. Theory

The atoms of which molecules are composed are held together by bonds of various types and lengths. These arrangements, as in the classical ball and spring configurations often presented in introductory chemistry, establish finite locations and discrete movements for each atom (ball) and bond (spring). These movements can be either vibrational-rotational stretching or bending of the chemical bonds. The frequencies of these movements are on the order of infrared radiation (IR). A given bond movement can be initiated by stimulating the molecule with IR of varying frequency. As the bond moves, it absorbs the characteristic energy associated with that movement. The frequencies and intensity of IR absorbed are specific for a compound and its concentration, providing a "fingerprint" which can be used as an analytical tool.

b. Miran Infrared Spectrophotometer

The Miran (acronym for miniature infrared analyzer) is a line of field IR spectrophotometers used to measure concentrations of vapors in ambient air.

It uses a variable-path gas cell. Several movable mirrors permit repeated passes, producing paths from several centimeters to several meters.

Field analysis presents problems not normally encountered in spectrophotometry in the laboratory. With lab instruments, the analyst can control the concentration of material entering the sample cell. To analyze uncontrollable gas the Miran must make repeated passes to achieve reliable results. Liquid or solid samples are preferable to gas samples because they possess more molecules than a gas of the same volume.

Additionally, the spectra of analyses of the same chemical in the liquid phase and gaseous phase are markedly different. In the gaseous state, the molecules are free to rotate, and inter molecular actions are at a minimum. The liquid state "locks" the molecules in a given structure.

c. Limitations

The Miran is designed for industrial hygiene work in occupational settings where known types of materials are generated and where 120-volt AC power is available. At hazardous waste sites, neither of these conditions is common, making Mirans of questionable value. They also have not been recognized by any approving agencies as being safe for use in a hazardous location. Basically, the Miran is designed for quantifying single one-or two-component mixtures. They should be used on a hazardous waste site with another analytical procedure such as gas chromatography.

C. Specific Survey Instruments

Specific survey instruments are devices that measure a specific material. Oxygen meters and direct-reading colorimetric tubes are often used at incidents involving hazardous substances.

1. Oxygen Meters

The oxygen content in a confined space is of prime concern to anyone about to enter that space. Removal of oxygen by combustion, reduction reactions, or displacement by gases or vapors is a hazard that response personnel cannot detect. Consequently, remote measurements must be made before anyone enters any confined space.

a. Theory

An oxygen detector uses an electrochemical sensor to determine the oxygen concentration in air. The sensor consists of: two electrodes, a sensing and a counting electrode; a housing containing a basic electrolytic solution; and a semipermeable Teflon membrane (Figure 1-6).

Oxygen molecules (O_2) diffuse through the membrane into the solution. Reactions between the oxygen and the electrodes produce a minute electric current which is directly proportional to the sensors's oxygen content. The current passes through the electronic circuit. The resulting signal is shown as a needle deflection on a meter, which is usually calibrated to read 0-10%, 0-25%, or 0-100% oxygen.

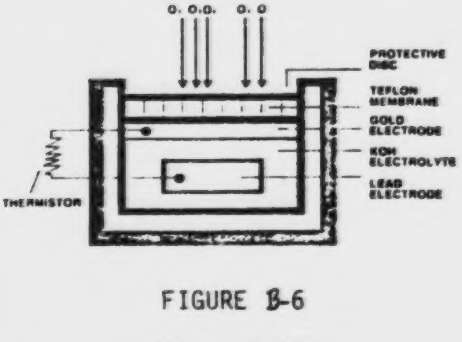


FIGURE B-6

OXYGEN DETECTOR

b. Limitations

The operation of oxygen meters depends on the absolute atmospheric pressure. The concentration of natural oxygen (to differentiate it from manufactured or generated oxygen) is a function of the atmospheric pressure at a given altitude.

At sea level, where the weight of the atmosphere above is greatest, more O_2 molecules are compressed into a given volume than at higher elevations. As elevation increases, this compression decreases, resulting in fewer O_2 molecules being "squeezed" into a given volume. Consequently, an O_2 indicator calibrated at sea level and operated at an altitude of several thousand feet will falsely indicate an oxygen-deficient atmosphere (less than 19.5%).

High concentrations of carbon dioxide (CO_2) shorten the useful life of the oxygen detector cell. Therefore, the unit can be used in atmospheres greater than 0.5% CO_2 only with frequent replacing or rejuvenating of the oxygen detector cell.

Although several instruments can measure an oxygen-enriched atmosphere (O_2 greater than 21%), no testing or other work should ever be performed under such conditions because a spark, arc or flame could lead to fire or explosion. Oxygen measurements are most informative when paired with combustible gas measurements. Together, they provide response personnel with quick and reliable data on the hazards they may encounter.

2. Direct-Reading Colorimetric Indicator Tubes

In evaluating hazardous waste sites, the need often arises to quickly measure a specific vapor or gas. Direct-reading colorimetric indicator tubes can successfully fill that need.

a. Theory

The interaction of two or more substances may result in chemical changes. This change may be as subtle as two clear liquids producing a third clear liquid, or as obvious as a colorless vapor and colored solid producing a differently colored substance. Indicator tubes use this latter phenomenon to estimate the concentration of a gas or vapor in air.

Colorimetric indicator tubes consist of an impregnated glass tube with an indicating chemical (Figure 1-7). The tube is connected to a piston cylinder- or bellows- type pump. A known volume of contaminated air is pulled at a predetermined rate through the tube. The contaminant reacts with the indicator chemical in the tube, producing a stain whose length is proportional to the contaminant's concentration. A preconditioning filter may precede the substrate to:

- Remove contaminants (other than the one in question) that may interfere with the measurement.
- React with a contaminant to change it into a compound that reacts with the indicating chemical.
- Completely change a nonindicating contaminant into an indicating one.

b. Limitations

Several indicating chemicals may be able to measure the concentration of a particular gas or vapor, each operating on a different chemical principle and each affected in varying degrees by temperature, air volume pulled through the tube, and interfering gases or vapors. A "true" concentration versus the "measured" concentration may vary considerably among and between manufacturers. To limit these sources of error, control the numerous types and manufacturers of tubes, and provide a degree of confidence to users, the National Institute of Occupational Safety and Health tests and certifies indicator tubes. Certified tubes have an accuracy of ± 35% at 1/2 the TLV of the chemical and ±25% at the TLV.

To improve performance of all tubes, they should be:

- Refrigerated prior to use to maintain shelf life of approximately 2 years.
- Calibrated and used at the same temperature.
- Calibrated with the pump prior to sampling (pressure test) and on a quarterly basis (volumetric test).

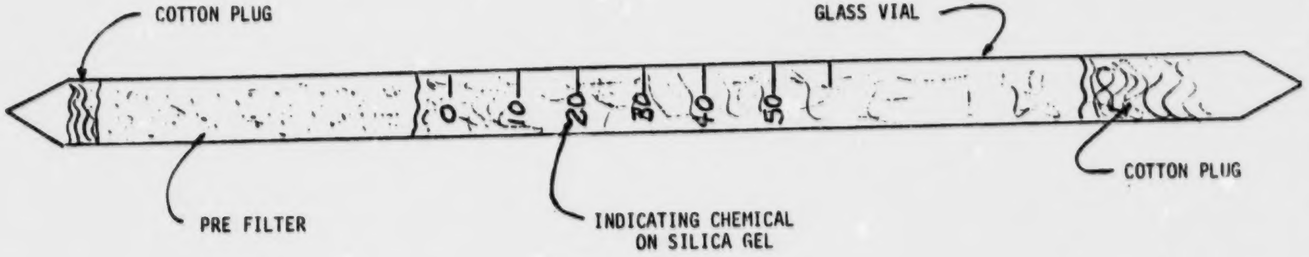


FIGURE B-7

DIRECT-READING COLORIMETRIC INDICATOR TUBE

Undoubtedly the greatest source of error is how the operator "reads" the endpoint. The jagged edge where contaminant meets indicator chemical makes it difficult to get accurate results from this seemingly simple test. A diligent and experienced operator should be able to accurately read the endpoint.

VII. CONCLUSION

A. Combined Instruments

Several instrument packages combine two or more detectors. For example, a combined hot wire detector for combustible gases and an oxygen sensor use a common pump, battery, and electronic circuit. Normally, each detector operates independently, thereby allowing one to be used even if the other is not working properly.

Combination units afford response personnel several advantages over single units, chiefly portability. Additionally, combined instruments may incorporate an adjustable alarm circuit that alerts the user to potentially hazardous conditions. This capacity frees the user of the need to take frequent meter readings and focuses attention on other hazards.

B Other Useful Instruments

Several manufacturers of micro-miniature electronic circuits and fuel cells have entered the field of specific contaminant analysis. These devices analyze the ambient atmosphere for the more insidious gases and vapors, such as hydrogen sulfide and carbon monoxide. Although their use is limited, they may be useful in certain situations.

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APPENDIX C

SAMPLING EQUIPMENT AND METHODS

I. INTRODUCTION

A variety of equipment and techniques are used for sampling at incidents involving hazardous materials. Using liquid and solid materials samplers, selecting sample containers and closures, preserving samples, and all are important to obtaining analytical data that give a true picture of conditions of the incident.

II. SAMPLERS

The various samplers currently available can be applied in certain situations, but they have limitations that must also be recognized (Table 3-1).

A. Liquids

1. Open-Tube/Drum Sampler

A glass open-tube is the most versatile of hazardous liquid samplers because of its wide range of applications, relatively low cost, and ease of operation.

Description: The open-tube sampler is made of hollow glass (or plastic tubing), usually 4 feet (ft.) long. The inside diameter (I.D.) is generally 1/4 - 1/2 inch (in.), depending on viscosity of sample. Open tubes made specifically for sampling (called drum samplers) can be purchased. The only difference is that drum samplers have a constricted orifice at the top to facilitate plugging the opening to maintain a vacuum in the tube.

Procedure for use

a. Slowly lower tube into the liquid to the desired depth. It may be desirable not to mix the contents of the container so that a more representative sample can be collected.

b. At desired depth, stopper tube with a rubber stopper or thumb or crease a piece of flexible tubing attached to the open end of the sample tube. Stoppering establishes a vacuum in the tube, enabling withdrawal of the sample from the container.

c. Slowly withdraw tube from vessel and expel sample into appropriate sample container. Avoid handling the portion of sampler that was in the liquid.

d. Dispose of tube on site by placing it back into the container that was sampled.

TABLE 3-1

SAMPLERS FOR HAZARDOUS MATERIALS

Sampler	Applications	Limitations	Suppliers
Open-tube/COLIWASA	Liquids, slurries	Not for containers over 1.5 meters (m.) (5 ft.) deep	Open-tube: Laboratory supply houses
Plastic		Not for materials containing ketones, nitrobenzene, dimethylformamide, mesityl oxide, tetrahydrofuran, or many common solvents such as acetone	COLIWASA: Nasco, 901 Janesville Ave., Fort Atkinson, WI 53538
Glass		Not for materials containing hydrofluoric acid and concentrated alkali solutions	
		COLIWASA may be difficult to decontaminate and may cause cross-contamination of samples	
Pond (dip) sampler	Liquids, sludges	Not for sampling beyond 3.5 m. (11.5 ft.)	Fabricate. Clamps available Cole-Parmer Instrument Co. 7425 N. Oak Park Ave Chicago, IL 60648
Manual pump	Liquids	Requires large amounts of disposable tubing that must be compatible with material	Local hardware stores and/or laboratory supply houses
Weighted bottle sampler	Liquids	Difficult to use with very viscous liquids. Exterior of sample bottle exposed to hazardous materials	Fabricate
Extended bottle sampler	Liquids	Difficult to use with very viscous liquids. Exterior of sample bottle exposed to hazardous materials	Ace Glass Company Vineland, NJ 08360
Kemmerer sampler	Liquids	Must be compatible with sample	Laboratory supply houses
Grain sampler	Granular solids	Limited application for sampling moist and sticky solids with a diameter of 0.6 cm (1/4 in.)	Laboratory supply houses
Sampling trier	Solids	Possible difficulty in retaining core sample of very dry granular materials during sampling	Laboratory supply houses
Trowel/scoop/ spoon	Solids, soil surface	Not for sampling deeper than 8 cm (3 in.). Difficult to obtain reproducible mass of samples	Laboratory supply houses
Waste pile	Loose solids	Not for sampling solid wastes with dimensions greater than half the diameter of the sampling tube	Fabricate from pipe
Soil auger (manual)	Soil deeper than 102-126 cm (3-4 in.)	Does not collect undisturbed core sample	Weyco Distribution, Sacramento, CA

2. Composite Liquid Waste Sampler (COLIWASA)

The composite liquid waste sampler (COLIWASA) is a valuable tool in some applications. In sampling hazardous liquids, however, it is difficult to decontaminate and may cause cross-contamination.

Description: The main parts of the COLIWASA are sampling tube, closure-locking mechanism, and closure system (Figure 3-1). The sampling tube consists of 5 ft. by 1 5/8 in. I.D. translucent pipe, usually polyvinyl chloride (PVC) or borosilicate glass plumbing tube. The closure-locking mechanism consists of a short-length, channeled aluminum bar attached to the sampler's stopper rod by an adjustable swivel. An aluminum bar serves both as a T-handle and lock for the sampler's closure system.

Procedure for Use:

a. Put sampler in open position by placing stopper rod handle in T-position and pushing rod handle until it sits against sampler's locking block.

b. Slowly lower sampler into liquid so that liquid inside and outside the tube are about the same. If the level inside the sampler tube is lower than outside sampler, sampling rate is too fast, resulting in a nonrepresentative sample.

c. When sampler stopper hits bottom of waste container, push the tube downward against stopper to close sampler. Lock sampler in close position by turning T-handle until it is upright and one end rests tightly on locking block.

d. Slowly withdraw the sampler from container.

e. Carefully discharge sample into a suitable sampler container by opening sampler. This is done by slowly pulling lower end of T-handle away from locking block, while lower end of sampler is positioned in a sample container.

3. Pond (Dip) Sampler

The pond (dip) sampler can be used to collect liquids or sludges from ponds, pits, lagoons, or open vessels, but only as far as its limited reach.

Description: The pond (dip) sampler consists of a container in an adjustable clamp attached to the end of a telescoping pole 8-15 ft. long. The pole can be of wood, plastic, or metal because the sample is collected in a jar or beaker which is secured in the clamp (Figure 3-2).

Procedure for use: Ladle liquids from into sample containers.

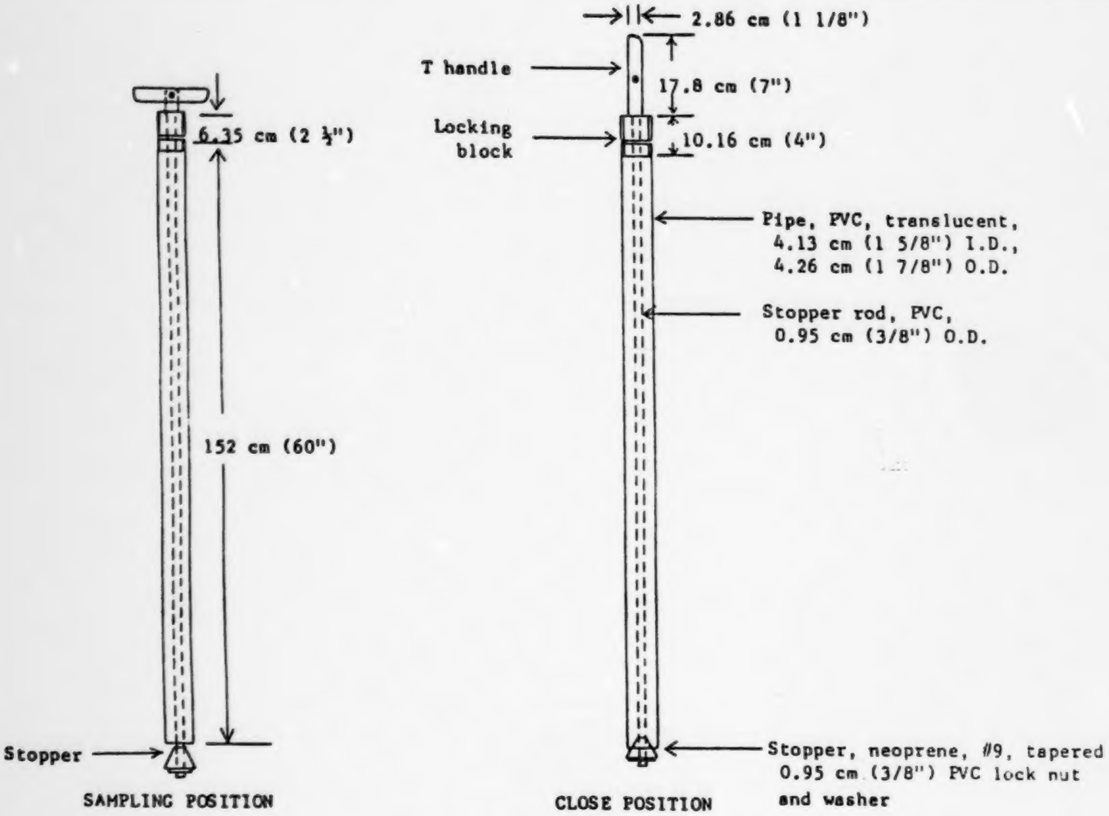
2.86 cm (1 1/8")
T handle
17.8 cm (7")
Locking block
10.16 cm (4")
6.35 cm (2 ½")
Pipe, PVC, translucent, 4.13 cm (1 5/8") I.D., 4.26 cm (1 7/8") O.D.
Stopper rod, PVC, 0.95 cm (3/8") O.D.
152 cm (60")
Stopper
Stopper, neoprene, #9, tapered 0.95 cm (3/8") PVC lock nut and washer
SAMPLING POSITION
CLOSE POSITION

FIGURE 3-1

COMPOSITE LIQUID WASTE SAMPLER (COLIWASA)

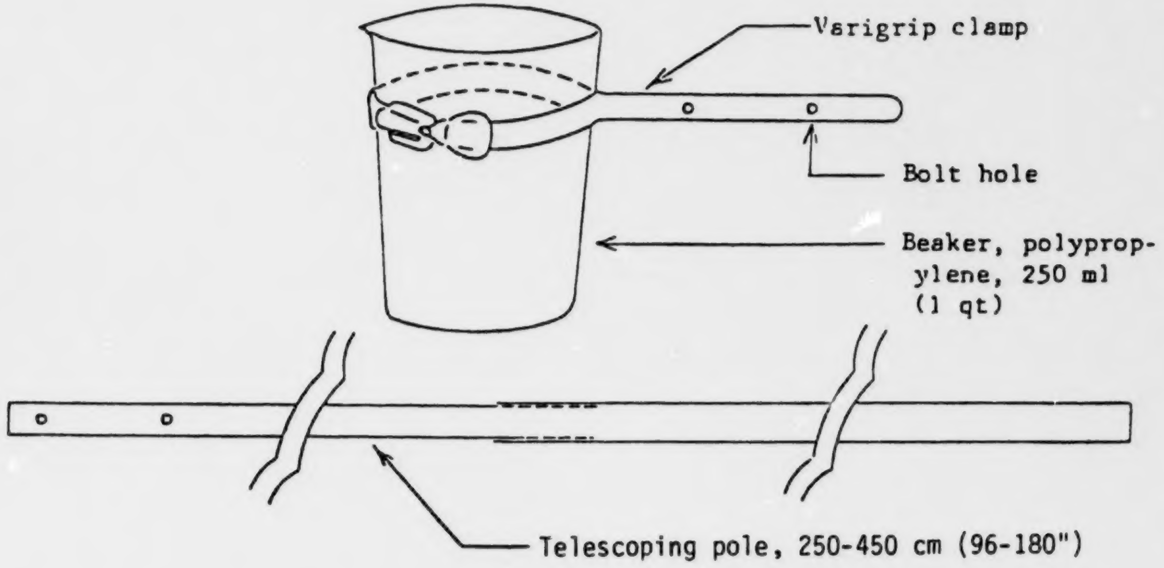
Varigrip clamp
Bolt hole
Beaker, polypropylene, 250 ml (1 qt)
Telescoping pole, 250-450 cm (96-180")

FIGURE 3-2

POND (DIP) SAMPLER

4. Manual Pumps

The principal drawback of manual pumps is that they require large amounts of disposable tubing, which must be compatible with the waste being sampled.

Description: Manual pumps most commonly operate by peristalsis, bellows, diaphragm or siphon. They are available in various sizes and configurations (Figure 3-3).

Procedure for use: Operate according to manufacturer's instructions. In most cases this involves placing sample inlet hose into liquid, then manually activating a crank or bellows. To avoid contamination of the pump, a liquid trap is inserted in the sample inlet hose where the sample is collected. The compatability of the plastic inlet hose with the sample must be determined to avoid sample contamination.

5. Weighted Bottle Sampler

Weighted bottle samplers are difficult to use in very viscous liquids. In addition, the outside of the bottle is exposed to the waste. This is undersirable if the bottle is used as the sample container.

Description: The weighted bottle sampler consists of a glass sinker, a bottle stopper, and a line for opening the bottle and lowering and raising the sampler during sampling (Figure 3-4). There are variations of this sampler, as illustrated in the American Society of Testing Materials (ASTM) methods D 270 and E 300. This sampler can be either fabricated or purchased.

Procedure for use:

a. Gently lower sampler into liquid to desired depth so as not to remove stopper prematurely.

b. Pull out stopper with a sharp jerk or sampler line.

c. Allow bottle to fill completely until air bubbles stop.

d. Raise sampler and cap bottle.

e. Wipe bottle, which can be used as sampler container.

Alternatives to the weighted bottle sampler are the Kemmerer sampler and the extended bottle sampler.

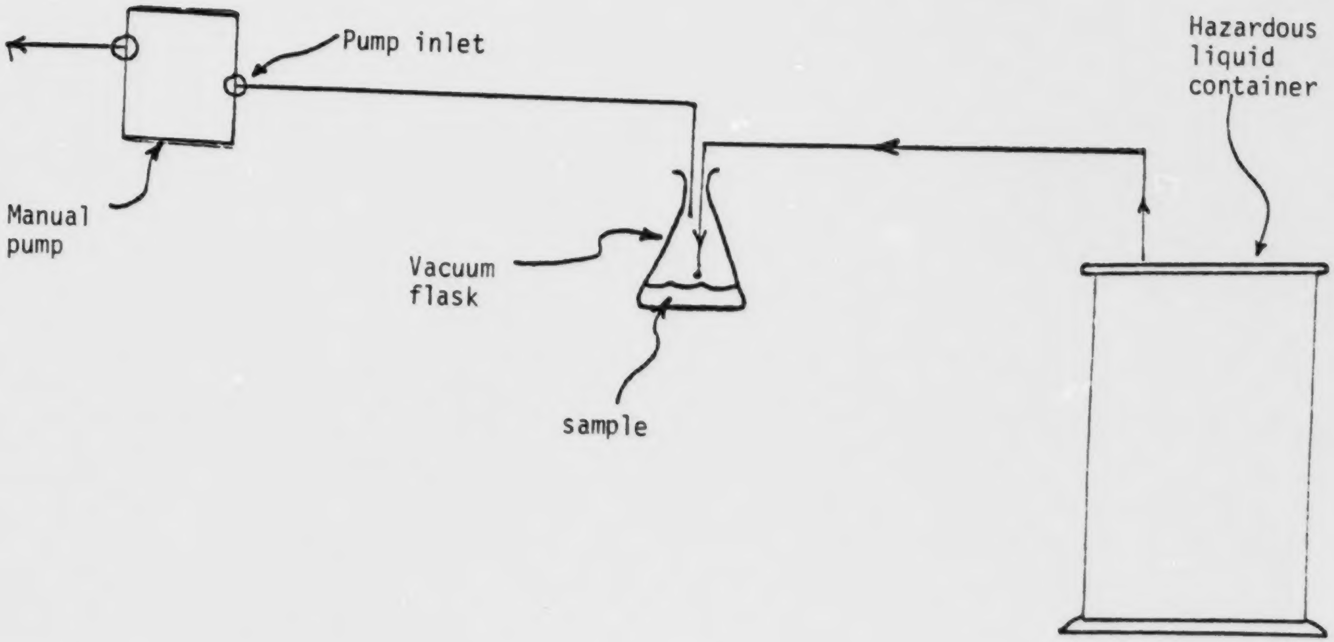

FIGURE 3-3

MANUAL PUMP

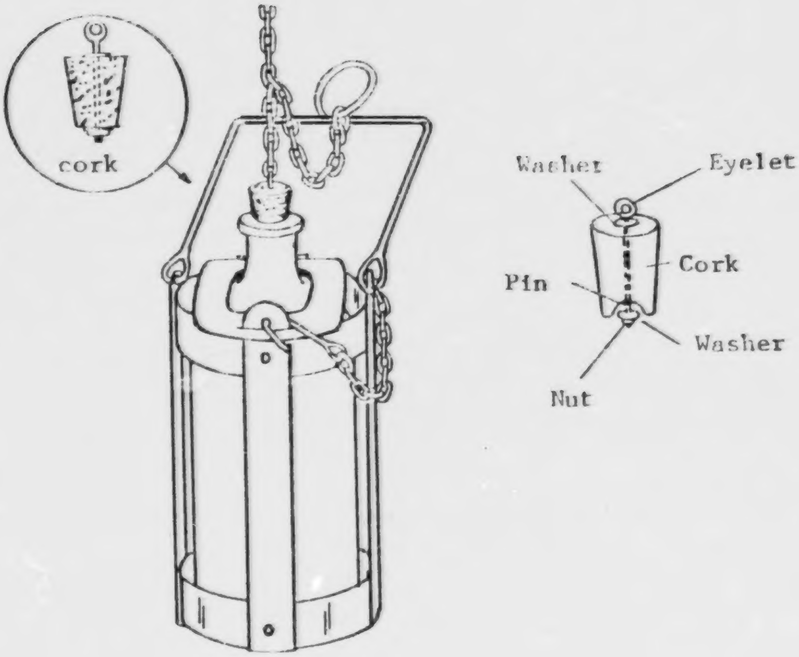

FIGURE 3-4

WEIGHTED BOTTLE SAMPLER

B. Solids

1. Grain Sampler

Grain samplers are best used for collecting granular or loose solids. Moist, compressed, and large particle solids are difficult to collect.

Description: The grain sampler consists of two slotted telescoping tubes, usually made of brass or stainless steel (Figure 3-5). The outer tube has a conical, pointed tip on one end that permits the sampler to penetrate the material being sampled. The sampler is opened and closed by rotating the inner tube. Grain samplers are generally 24 to 40 in. long by 1/2 to 1 1/2 in. in diameter.

Procedure for use:

a. Insert sampler (in the close position) into material being sampled from a point near a top edge or corner, through center, and to a point diagonally opposite point of entry.

b. Rotate inner tube into open position.

c. Wiggle sampler a few times to allow materials to enter open slits.

d. Place sampler in close position and withdraw.

e. Place sampler in a horizontal position, if possible, with slots facing upward.

f. Rotate and slide out outer tube from the inner tube.

g. Transfer sample in inner tube into a suitable sample container. If inner tube is not removable, turn sampler upside down and pour contents out of an opening in end of the tube.

h. Store sampler in a plastic bag until decontamination.

2. Sampling Trier

Sampling triers are used to sample compressed solids. One difficulty, however, is the removal of the core sample cut with the trier.

Description: A typical sampling trier is a long tube about 24 to 40 in. long and 1/2 to 1 in. in diameter, with a slot that extends almost its entire length (Figure 3-6). The tip and edges of the tube slot are sharpened to allow the trier to cut a core when rotated in a solid material. Sampling triers are usually made of stainless steel with wooden handles.

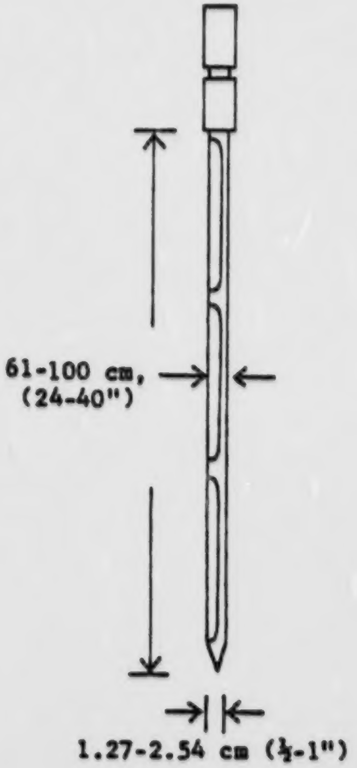

FIGURE 3-5

GRAIN SAMPLER

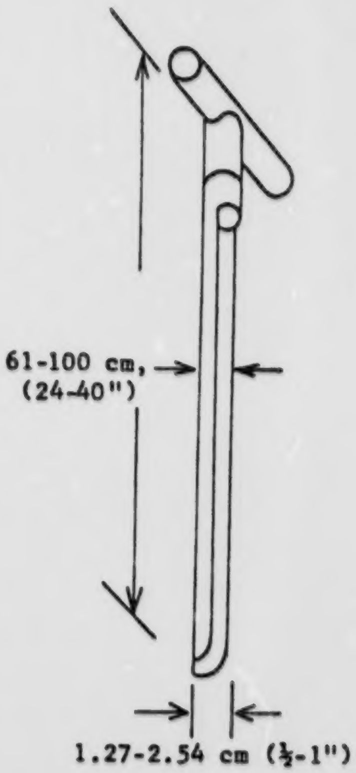

FIGURE 3-6

SAMPLING TRIER

Procedure for use

a. Insert trier into solid material at 0 to 45° angle from horizontal to minimize spillage from sampler. Tilt containers if necessary.

b. Rotate trier once or twice to cut a core of material.

c. Slowly withdraw trier, making sure that slot is facing upward.

d. Transfer sample into suitable container with aid of a spatula and/or brush.

e. Store sampler in a plastic bag until decontamination.

3. Waste Pile Sampler

The waste pile sampler is used to sample wet and large-diameter solids.

Description: A waste pile sampler is essentially a large sampling trier (Figure 3-7). It is commercially available, but it is easy to fabricate from sheet metal or plastic pipe. Polyvinyl chloride plumping pipe 5 ft. long by 1 1/4 in. I.D. with 1/8 in. wall thickness is adequate. The pipe is sawed lengthwise (about 60/40 split) until the last 4 in. The narrower piece is sawed off, leaving a slot in the pipe. The edges of the slot and the tip of the pipe are sharpened to permit the sampler to cut into the material being sampled. The unsplit 4 in. of the pipe serves as the handle.

Procedure for use:

a. Insert sampler into material being sampled at 0 to 45° from horizontal, tilting container if necessary.

b. Rotate sampler two or three times in order to cut a core of material.

c. Slowly withdraw sampler making sure that the slot is facing upward.

d. Transfer sample into a suitable container with the aid of a spatula and/or brush.

e. Store sampler in a plastic bag until decontamination.

4. Trowel/Scoop/Spoon

Trowels, scoops, and spoons are inexpensive, but they can sample only to a depth of 4-5 in.

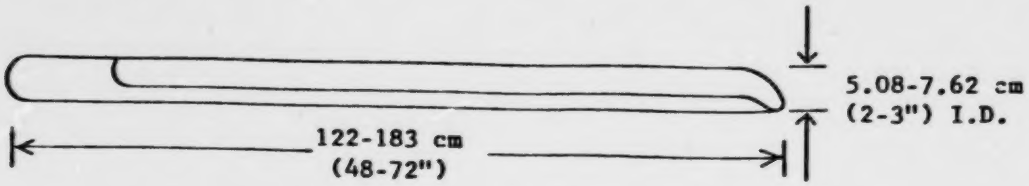

FIGURE 3-7

WASTE PILE SAMPLER

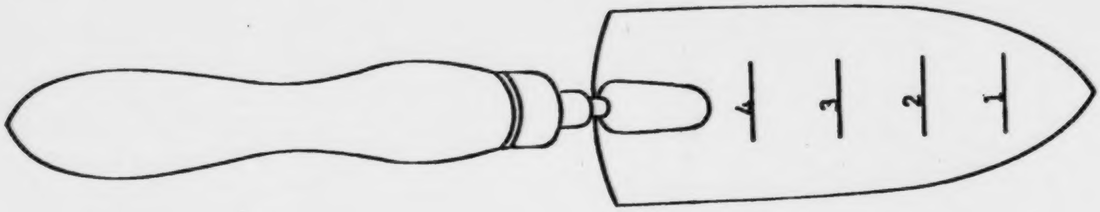

FIGURE 3-8

TROWEL

Description: A garden-variety trowel looks like a small shovel. The blade is usually about 3 by 5 in. with a sharp tip (Figure 3-8). A laboratory scoop is similar, but the blade is usually more curved and has a closed upper end to contain material. Scoops come in different sizes and materials. Stainless steel or polypropylene scoops with 2 3/4 by 6 in. blades are preferred. Another alternative for small samples is a stainless steel table spoon.

Procedure for use:

a. Collect small, equal portions of sample from surface or near the surface or material to be sampled.

b. Deposit samples in a suitable container.

c. Dispose of sampler or place in a plastic bag until decontamination.

5. Soil Auger (Manual)

A manual soil auger can sample deeper and more compacted soils and solids than other samplers, but it is difficult to get the sample in a container.

Description: The soil auger consists of a hard metal central shaft and sharpened spiral blades. When the tool is rotated clockwise by its handle, it cuts the soil as it moves downward and deposits most of the loose soil upward. Augers are available in various sizes and configurations.

Procedure for use: Follow manufacturer's instructions.

C. Cleaning and Storage Procedures

All samplers must be clean before use. After use, they must be washed with warm detergent solution (for example, Liquinox or Alconox), rinsed several times with tap water, rinsed with distilled water, drained of excess water, and air dried, dried with a stream of warm, dry air, or wiped dry. Samplers used on petroleum products and oil residues may first have to be wiped with absorbent cloth to eliminate the residues. The equipment is then rinsed with an organic solvent, followed by washing with detergent solution and rinsing with water. A necessary piece of equipment for cleaning the tube of a COLIWASA is a bottle brush that fits tightly in the tube. The brush is connected to a rod long enough to reach the entire length of the sampler tube. This ramrod and fiber-reinforced paper towels clean the COLIWASA tube quickly.

Improper cleaning of sampling equipment will cause cross contamination of samples. Such contamination is particularly important in samples taken for legal or regulatory purposes. Also, contamination becomes important when sampling wastes from different sources at the same time. If samples are to be taken for legal or regulatory purposes, or if they are expected to contain low concentrations of hazardous substances, a clean, unused sampler is needed.

If the cleaning process has the potential for producing toxic fumes, ensure adequate ventilation. If the washings are hazardous, store them in closed waste containers and dispose of them properly in approved disposal sites. Names of nearby sites may be obtained by calling the agency in the State responsible for regulation of hazardous wastes. Store clean samplers in a clean and protected area; polyethylene plastic tubes or bags are usually adequate.

III. CONTAINERS, CLOSURES/CLOSURE LINERS

A. Containers

The most imporant factors to consider when chosing containers for hazardous material samples are compatibility, resistance to breakage, and volume. Containers must not melt, leach, rupture, or leak as a result of chemical reactions with constituents of a sample. Thus it is important to have some idea of the composition of the sample. The containers must have walls thick enough to survive sample collection and transport to the laboratory. Containers with wide mouths make it easier to transfer samples from samplers. Also, the containers must be large enough to contain the required volume of the sample or the entire volume of a sampler.

Plastic and glass containers are generally used for collection and storage of hazardous material samples. Commonly available plastic containers are made of high-density or linear polyethylene (LPE), convential polyethylene, polypropylene, polycarbonate, Teflon FEP (fluorinated ethylene propylene), polyvinyl chloride (PVC), or polymethylpentene. Teflon FEP is the most inert, giving it the widest range of application. Plastic containers are used only when the constituents of the material are known not to react with the plastic.

Glass containers are relatively inert to most chemicals and can be used to collect and store almost all hazardous material samples. Two exceptions are strong alkali solutions and hydrofluoric acid. Glass bottles with wide mouths (to faciliate sample collection) are recommended for samples containing petroleum distillates, chlorinated hydrocarbons, pesticides, solvents, and other substances incompatible with plastic.

Several types of glass containers are available. Flint glass bottles are cheap and available in various shapes and sizes. Borosilicate glass is more inert, but the selection of containers is smaller. Also, it is more expensive.

B. Closures/Closure Liners

Sample containers must have tight, screw-type lids. Plastic bottles are usually provided with screw caps made of the same material as the bottles. Cap liners usually are not required. Glass containers usually come with glass or rigid plastic screw caps. Caps often have paper liners coated with wax. Other liner materials are polyethylene, polypropylene, neoprene, and Teflon FEP.

For containing hydrocarbons, pesticides, and petroleum residues, caps with Teflon liners are recommended for use with amber glass bottles. Teflon liners may be purchased from plastic specialty supply houses.

The selection of containers, closures, and linings must be coordinated with the laboratory, which may require specific containers for certain analyses.

Containers (type and size) must comply with DOT regulations.

IV PRESERVATION AND STORAGE OF SAMPLES

Samples should be analyzed immediately after collection for best results. Hazardous wastes are such complex mixtures that it is difficult to predict exactly the physical, biological, and chemical changes that occur in the samples. The pH may change significantly in a matter of minutes, sulfides and cyanides may be oxidized or evolve as gases, and hexavalent chromium may slowly be reduced to the trivalent state. Certain cations may be partly lost as they are adsorbed on the walls of the sample containers. Microorganisms may grow in certain constituents. Volatile compounds may be rapidly lost.

In a number of cases, such changes may be slowed down or prevented by refrigeration at 4 to 6°C, or by adding preservatives. However, these treatments may be only partially effective. Refrigeration may reduce loss of volatile components and acid gases such as hydrogen sulfide and hydrogen cyanide, but it also introduces the possibility that some salts may precipitate at lower temperatures. On warming to room temperature for analysis, the precipitates may not redissolve, thus giving inaccurate results. Preservatives may retard constituents to stable hydroxides, salts, or compounds, but they may also convert other forms (such as the products of nitration, sulfonation, and oxidation, of organic components). Thus, subsequent analyses may not identify the original components or concentrations.

Safety must also be considered because a preservative may be highly reactive with the sample. Addition of a preservative may change the DOT packaging, labeling, and shipping requirements for a sample. Shipping hazardous samples packed in ice may not be permitted by DOT regulations (Refer to Part 5: Hazardous Material Sample Packaging, Labeling, and Shipping).

APPENDIX D

STANDARD OPERATING SAFETY GUIDES

PART 1

ENVIRONMENTAL INCIDENTS

I. INTRODUCTION

An environmental incident involves a release or threat of a release of hazardous substances that pose an imminent and substantial danger to public health and welfare or the environment. Each incident presents special problems. Response personnel must evaluate these problems and determine an effective course of action to mitigate the incident.

Any incident represents a potentially hostile situation. Chemicals that are combustible, explosive, corrosive, toxic, or reactive, along with biological and radioactive materials can affect the general public or the environment as well as response personnel. Workers may fall, trip, be struck by objects, or be subject to danger from electricity and heavy equipment. Injury and illness may also occur due to physical stress and climate. While the response activities needed at each incident are unique, there are many similarities. One is that all responses require protecting the health and ensuring the safety of the responders.

II. EXPOSURE TO TOXIC SUBSTANCES

Toxic (including radioactive material and etiological agents) or chemically active substances present a special concern because they can be inhaled, ingested, absorbed through the skin, or destructive to the skin. They may exist in the air or due to site activities become airborne or splash on the skin. The effects of these substances can vary significantly. Ingested or inhaled the substances can cause no apparent illness or they can be fatal. On the skin they can cause no demonstrable effects. Others however can damage the skin, or be absorbed, leading to systemic toxic effects.

Two types of potential exposure exist:

- Acute: Exposures occur for relatively short periods of time, generally hours to 1-2 days. Concentrations of toxic air contaminants which may be inhaled are high relative to their protection criteria. In addition, substances may contact the skin directly through splashes, immersion, or air with serious results.
- Chronic: Exposures occur over longer periods of time, generally months to years. Concentrations of toxic air contaminants which may be inhaled are relatively low. Direct skin contact by immersion, splash, or air involves substances exhibiting low dermal activity.

In general, acute exposures to chemicals in air are more typical in transportation accidents, fires, or releases at chemical manufacturing or storage facilities. Acute air exposures do not persist for long periods of time. Acute skin exposures occur when workers must be close to the substances in order to control the release (patching a tank car, off-loading a corrosive material, etc.) or contain and treat the spilled material. Once the immediate problems have been alleviated, exposures tend to become more chronic in nature as cleanup progresses.

Chronic exposures usually are associated with longer-term remedial operations. Contaminated soil and debris from emergency operations may be involved, soil and ground water may be polluted, or impoundment systems may contain diluted chemicals. Abandoned waste sites represent chronic problems. As activities start at these sites, however, personnel engaged in sampling, handling containers, bulking compatible liquids, etc. face an increased risk of acute exposures to splashes, or the generation of vapors, gases, or particulates.

At any specific incident, the hazardous properties of the materials may only represent a potential threat. For example, if a tank car of liquified natural gas involved in an accident remains intact, the risk from fire and explosion is low. In other incidents, hazards are real and risks high as when toxic or flammable vapors are being released. The continued health and safety of response personnel requires that the hazards - real or potential - at an episode be assessed and appropriate preventive measures instituted.

III. HEALTH AND SAFETY OF RESPONSE PERSONNEL

To reduce the risks to workers responding to hazardous substance incidents, an effective health and safety program must be implemented. This would include, as a minimum:

- Safe work practices.
- Engineered safeguards.
- Medical surveillance.
- Environmental and personnel monitoring.
- Personnel protective equipment.
- Education and training.
- Standard operating safety procedures.

As part of a comprehensive program, standard operating safety procedures provide instructions on how to accomplish specific tasks in a safe manner. In concept and principle, standard operating safety procedures are independent of the type of incident. Their applicability at a particular incident must be determined and necessary modifications made to match prevailing conditions. For example, personnel protective equipment, in principle, is an initial consideration for all incidents; however, its need and the type of equipment required is based on a case-by-case evaluation. Likewise, someone must make the first entry onto a site. The exact entry procedure to be used can only be determined after assessing the conditions prevailing at that incident.

The purpose of this document is to provide standard operating safety guides related to site control and entry. The guidance included is not meant to be a comprehensive treatment of the subjects covered. Rather, it is meant to be used to complement professional training, experience, and knowledge.

IV. OCCUPATIONAL HEALTH AND SAFETY POLICY

EPA's Occupational Health and Safety staff is responsible for developing, supporting, and evaluating a program to protect the health and safety of EPA employees. The Standard Operating Safety Guides complement, and supplement the policies, procedures, and practices contained in EPA's Occupational Health and Safety Manual, in particular, with Chapter 9 - Hazardous Substances Responses, EPA Order 1440.2 - Health and Safety Requirments for Personnel Engaged in Field Activities, and EPA Order 1440.3 - Respiratory Protection.

PART 2

STANDARD OPERATING SAFETY PROCEDURES

I. GENERAL

There are many guides or procedures for performing the variety of tasks associated with responding to environmental episodes involving hazardous substances. These may be administrative, technical, or management-oriented. All these procedures are intended to provide uniform instructions for accomplishing a specific task. In addition to other types of procedures, safety-oriented operating procedures are needed. The purpose of this document is to provide selected standard operating safety guides which can be used to develop more specific procedures.

II. DEVELOPMENT OF STANDARD OPERATING SAFETY PROCEDURES

A major consideration in responding to accidental releases of hazardous substances or incidents involving abandoned hazardous waste sites is the health and safety of response personnel. Not only must a variety of technical tasks be conducted efficiently to mitigate an incident, but they must be accomplished in a manner that protects the worker. Appropriate equipment and trained personnel, combined with standard operating procedures, help reduce the possibility of harm to response workers.

For procedures to be effective:

- They must be written in advance. Developing and writing safe, practical procedures is difficult when prepared under the stress of responding to an incident.
- They must be based on the best available information, operational principles, and technical guidance.
- They must be field-tested, reviewed, and revised when appropriate by competent safety professionals.
- They must be understandable, feasible, and appropriate.
- All personnel involved in site activities must have copies of the safety procedures and be briefed on their use.
- Response personnel must be trained and periodically retrained in personnel protection and safety.

III. RESPONSE ACTIVITIES

Many of the procedures involved in response activities are primarily concerned with health and safety. In concept and principle, these are generic and independent of the type of incident. They are adapted or modified to meet site-specific requirements. Each hazardous materials incident must be evaluated to determine its hazards and risks. Various types of environmental samples or measurements may be needed initially to determine the hazards or to provide additional information for continuing assessment. Personnel must go on-site to accomplish specific tasks. Efforts are required to prevent or reduce harmful substances from migrating from the site due to natural or human activities. Containment, cleanup, and disposal activities may be required. Each of these activities requires that safety procedure be developed or existing procedures be adapted so that response personnel are protected.

IV. OPERATING GUIDES

The standard operating safety guides that follow cover primarily site control and entry. These guides illustrate technical considerations necessary in developing standard instructions. For a given incident, the procedures recommended should be adapted to conditions imposed by that specific situation.

PART 3

SITE ENTRY - GENERAL MEASURES AND REQUIREMENTS

I. INTRODUCTION

Personnel responding to environmental episodes involving chemical substances encounter conditions that are unsafe or potentially unsafe. In addition to the danger due to the physical, chemical, and toxicological properties of the material present, other types of hazards electricity, water, heavy equipment, falling objects, loss of balance, or tripping, for example - can have an adverse effect on personnel. This part discusses safety measures and precautions associated only with the hazardous nature of chemical compounds.

II. SAFETY PRACTICES

A. Personal Precautions

1. Eating, drinking, chewing gum or tobacco, smoking, or any practice that increases the probability of hand-to-mouth transfer and ingestion of material is prohibited in any area designated contaminated.

2. Hands and face must be thoroughly washed upon leaving the work area.

3. Whenever decontamination procedures for outer garments are in effect, the entire body should be thoroughly washed as soon as possible after the protective garment is removed.

4. No facial hair which interferes with a satisfactory fit of the mask-to-face-seal is allowed on personnel required to wear respirators.

5. Contact with contaminated or suspected contaminated surfaces should be avoided. Whenever possible, do not walk through puddles, leachate, discolored surfaces, kneel on ground, lean, sit, or place equipment on drums, containers, or the ground.

6. Medicine and alcohol can potentiate the effects from exposure to toxic chemicals. Prescribed drugs should not be taken by personnel on response operations where the potential for absorption, inhalation, or ingestion of toxic substances exists unless specifically approved by a qualified physician. Alcoholic beverage intake should be minimized or avoided during response operations.

B. Site Safety Plans

1. A Site Safety Plan must be developed for all phases of site operations and made available to all personnel. Unless time precludes it, the plan must be written and posted.
2. All personnel must be familiar with standard operating safety procedures and any additional instructions and information contained in the Site Safety Plan.
3. All personnel must adhere to the information contained in the Site Safety Plan.

C. Operations

1. All personnel going on-site must be adequately trained and thoroughly briefed on anticipated hazards, equipment to be worn, safety practices to be followed, emergency procedures, and communications.
2. Any required respiratory protective devices and clothing must be worn by all personnel going into areas designated for wearing protective equipment.
3. Personnel on-site must use the buddy system when wearing respiratory protective equipment. As a minimum, a third person, suitably equipped as a safety backup, is required during initial entries.
4. Visual contact must be maintained between pairs on-site and safety personnel. Entry team members should remain close together to assist each other during emergencies.
5. During continual operations, on-site workers act as safety backup to each other. Off-site personnel provide emergency assistance.
6. Personnel should practice unfamiliar operations prior to doing the actual procedure.
7. Entrance and exit locations must be designated and emergency escape routes delineated. Warning signals for site evacuation must be established.
8. Communications using radios, hand signals, signs, or other means must be maintained between initial entry members at all times. Emergency communications should be prearranged in case of radio failure, necessity for evacuation of site, or other reasons.

9. Wind indicators visible to all personnel should be strategically located throughout the site.

10. Personnel and equipment in the contaminated area should be minimized, consistent with effective site operations.

11. Work areas for various operational activities must be established.

12. Procedures for leaving a contaminated area must be planned and implemented prior to going on-site. Work areas and decontamination procedures must be established based on expected site conditions.

III. MEDICAL PROGRAM

To safeguard the health of response personnel, a medical program must be developed, established, and maintained. This program has two essential components: routine health care and emergency treatment.

A. Routine Health Care

Routine health care and maintenance should consist of at least:

1. Pre-employment medical examinations to establish the individual's state of health, baseline physiological data, and ability to wear personnel protective equipment. The frequency and type of examination to be conducted thereafter should be determined by medical personnel knowledgeable in the area of toxicology.

2. Arrangements to provide special medical examinations, care, and counseling in case of known or suspected exposures to toxic substances. Any special tests needed depend on the chemical substance to which the individual has been exposed.

B. Emergency Medical Care and Treatment

The Medical Program must address emergency medical care and treatment of response personnel, including possible exposures to toxic substances and injuries resulting from accidents or physical hazards. The following items should be included in emergency care provisions:

1. Name, address, and telephone number of the nearest medical treatment facility. This should be conspicuously posted. A map and directions for locating the facility, plus the travel time, should be readily available.

2. The facility's ability to provide care and treatment of personnel exposed or suspected of being exposed to toxic (or

otherwise hazardous). If the facility lacks toxicological capability, arrangements should be made for consultant services.

3. Administration arrangements for accepting patients.

4. Arrangements to quickly obtain ambulance, emergency, fire, and police services. Telephone numbers and procedures for obtaining these services should be conspicuously posted.

5. Emergency showers, eye wash fountains, and first aid equipment readily available on-site. Personnel should have first aid and medical emergency training.

6. Provisions for the rapid identification of the substance to which the worker has been exposed (if this has not previously been done). This information must be given to medical personnel.

7. Procedures for decontamination of injured workers and preventing contamination of medical personnel, equipment, and facilities.

IV. EDUCATION AND TRAINING

All personnel involved in responding to environmental incidents must be trained to carry out their response functions. Training must be provided in the use of all equipment, including respiratory protective apparatus and protective clothing; safety practices and procedures; general safety requirements; advanced first aid; and hazard recognition and evaluation.

Safety training must be a continuing part of the total response program. Periodic retraining and practice sessions not only create a high degree of safety awareness, but also help to maintain proficiency in the use of equipment and knowledge of safety requirements.

V. QUALIFIED SAFETY PERSONNEL

Personnel responding to chemical incidents must make many complex decisions regarding safety. Making these decisions correctly requires more than elementary knowledge. For example, selecting the most effective personnel protective equipment requires not only expertise in the technical areas of respirators, protective clothing, air monitoring, physical stress, etc., but also experience and professional judgment. Only a competent, qualified person (specialist) has the technical judgment to evaluate a particular incident and determine the appropriate safety requirements. This individual, through a combination of professional education, on-the-job experience, specialized training, and continual study, acquires expertise to make sound decisions.

VI. STRESS

A. Introduction

Both physiological and psychological stress effect response personnel. Under certain conditions, stress contributes significantly to accidents and harms workers in other ways. To reduce the potential for abnormal physical stress or mental anxiety:

1. Workers must be periodically examined by medical authorities to determine if they are physically, and if possible, psychologically fit to perform their jobs.

2. Continual practice and training must be provided in using personnel protective equipment, especially the self-contained breathing apparatus and chemical-resistant protective clothing.

3. An effective safety program must be implemented and a concerted effort made to protect the worker. These actions help assure personnel that their health and safety will be protected now and in the future.

B. Weather

Adverse weather conditions are important considerations in planning and conducting site operations. Hot or cold weather can cause physical discomfort, loss of efficiency, and personal injury. Of particular importance is heat stress resulting when protective clothing decreases natural body ventilation. Heat stress can occur even when temperature are moderate. One or more of the following recommendations will help reduce heat stress:

1. Provide plenty of liquids. To replace body fluids (water and electrolytes) lost due to sweating, use a 0.1% salt water solution, more heavily salted foods, or commercial mixes. The commercial mixes may be preferable for those employees on a low-sodium diet.

2. Provide cooling devices to aid natural body ventilation. These devices, however, add weight, and their use should be balanced against worker efficiency. Long cotton underwear act as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing. It should be the minimum undergarment worn.

3. Install mobile showers and/or hose-down facilities to reduce body temperature and cool protective clothing.

4. In extremely hot weather, conduct nonemergency response operations in the early morning or evening.

5. Ensure that adequate shelter is available to protect personnel against heat, cold, rain, snow, etc., which decrease physical efficiency and increase the probability of accidents.

6. In hot weather, rotate workers wearing protective clothing.

C. Heat Stress Monitoring

For monitoring the body's recuperative ability to excess heat,

one or more of the following techniques should be used as a screening mechanism. Monitoring of personnel wearing protective clothing should commence when the ambient temperature is 70 degrees Fahrenheit or above. Frequency of monitoring should increase as the ambient temperature increases or if slow recovery rates are indicated. When temperatures exceed degrees F workers must be monitored for heat stress after every work period.

1. Heart rate (HR) should be measured by the radial pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 110 beats per minute. If the HR is higher, the next work period should be shortened by 10 minutes (or 33%), while the length of the rest period stays the same. If the pulse rate is 100 beats per minute at the beginning of the next rest period, the following work cycle should be shortened by 33%.

2. Body temperature should be measured orally with a clinical thermometer as early as possible in the resting period. Oral temperature (OT) at the beginning of the rest period should not exceed 99 degrees Fahrenheit. If it does, the next work period should be shortened by 10 minutes (or 33%), while the length of the rest period stays the same. However, if the OT exceeds 99.7 degrees Fahrenheit at the beginning of the next period, the following work cycle should be further shortened by 33%. OT should be measured again at the end of the rest period to make sure that it has dropped below 99 degrees Fahrenheit.

3. Body water loss (BWL) due to sweating should be measured by weighing the worker in the morning and in the evening. The clothing worn should be similar at both weighings; preferably the worker should be nude. The scale should be accurate to plus or minus 1/4 lb. BWL should not exceed 1.5% of the total body weight. If it does, workers should be instructed to increase their daily intake of fluids by the weight lost.

Ideally, body fluids should be maintained at a constant level during the work day. This requires replacement of salt lost in sweat as well.

4. Good hygienic standards must be maintained by frequent change of clothing and daily showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should immediately consult medical personnel.

D. Effects of Heat Stress

If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur ranging from mild (such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement) to fatal. Standard reference books should be consulted for specific first aid treatment. Medical help must be obtained

for the more serious conditions.

Heat-related problems are:

- Heat rash: caused by continuous exposure to heat and humid air and aggravated by chafing clothes. Decreases ability to tolerate heat as well as being a nuisance.

- Heat cramps: caused by profuse perspiration with inadequate fluid intake and chemical replacement (especially salts). Signs: muscle spasm and pain in the extremities and abdomen.

- Heat exhaustion: caused by increased stress on various organs to meet increased demands to cool the body. Signs: shallow breathing; pale, cool, moist skin; profuse sweating; dizziness and lassitude.

- Heat stroke: the most severe form of heat stress. Body must be cooled immediately to prevent severe injury and/or death. Signs and symptoms are: red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; coma. Medical help must be obtained immediately.

E. Effects of Cold Exposure

Persons working outdoors in temperatures at or below freezing may be frostbitten. Extreme cold for a short time may cause severe injury to exposed body surfaces, or result in profound generalized cooling, causing death. Areas of the body which have high surface area-to-volume ratio such as fingers, toes, and ears, are the most susceptible.

Two factors influence the development of a cold injury: ambient temperature and the velocity of the wind. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. For instance, 10 degrees Fahrenheit with a wind of 15 miles per hour (mph) is equivalent in chilling effect to still air at -18 degrees Fahrenheit.

As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. Additionally, water conducts heat 240 times faster than air. Thus, the body cools suddenly when chemical-protective equipment is removed if the clothing underneath is perspiration soaked.

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage. Frostbite of the extremities can be categorized into:

- Frost nip or incipient frostbite: characterized by suddenly blanching or whitening of skin.

- Superficial frostbite: skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.

- Deep frostbite: tissues are cold, pale, and solid; extremely serious injury.

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. Its symptoms are usually exhibited in five stages: 1) shivering, 2) apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95 degrees Fahrenheit, 3) unconsciousness, glassy stare, slow pulse, and slow respiratory rate, 4) freezing of the extremities, and finally, 5) death.

Standard reference books should be consulted for specific first aids treatments. Medical help must be obtained for the more serious conditions.

F. Indicators of Toxic Exposure Effects

- Observable

  -- changes in complexion, skin discoloration

  -- lack of coordination

  -- changes in demeanor

  -- excessive salivation, pupillary response

    - changes in speech pattern

- Non-Observeable
    - headaches
    - dizziness
    - blurred vision
    - cramps
    - irritation of eyes, skin, or respiratory tract

VII. SUMMARY

The health and safety of response personnel are major considerations in all response operations. All site operation planning must incorporate an analysis of the hazards involved and procedures for preventing or minimizing the risk to personnel. The Site Safety Plan establishes the safety practices and procedures to be followed so that the welfare and safety of workers are protected. The plan must evaluate both the nature of the chemical compounds present and other hazards that could affect response personnel.

PART 4

SITE ENTRY - SURVEY AND RECONNAISSANCE

I. INTRODUCTION

The team initially entering the site is to accomplish one or more of the following objectives:

- Determine the hazards that exist or potentially exist affecting public health, the environment, and response personnel.
- Verify existing information and/or obtain information about the incident.
- Evaluate the need for prompt mitigation.
- Collect supplemental information to determine the safety requirements for personnel initially and subsequently entering the site.

Before the team enters the site, as much information as possible should be collected, depending on the time available, concerning the type of hazards, degree of hazard(s), and risks which may exist. Based upon available information (shipping manifests, transportation placards, existing records, container labels, etc.) or off-site studies, the team assesses the hazards, determines the need to go on-site, and identifies initial safety requirements.

II. PRELIMINARY ON-SITE EVALUATION

The initial on-site survey is to determine, on a preliminary basis, hazardous or potentially hazardous conditions. The main effort is to rapidly identify the immediate hazards that may affect the public, response personnel, and the environment. Of major concern are the real or potential dangers - from, fire, explosion, airborne contaminants and to a lesser degree raiation and oxygen deficient atmospheres.

A. Organic Vapors and Gases

If the type of organic substance involved in an incident is known and the material is volatile or can become airborne, air measurements for organics should be made with one or more appropriate, properly calibrated survey instruments.

When the presence or types of organic vapors/gases are unknown, instruments such as a photoionizer (HNU Systems*) and/or a portable gas chromatograph (Foxboro Systems OVA*), operated in the total readout mode, should be used to detect organic vapors.

Until specific constituents can be identified, the readout indicates total airborne substances to which the instrument is responding. Identification of the individual vapor/gas constituents may permit the instruments to be calibrated to these substances and used for more specific and accurate analysis.

Sufficient data should be obtained during the initial entry to map or screen the site for various levels of organic vapors. These gross measurements may be used on a preliminary basis to: 1) determine levels of personnel protection, 2) establish site work zones, and 3) select candidate areas for more thorough qualitative and quantitative studies.

Very high readings on the HNU or OVA may also indicate the displacement of oxygen or the presence of combustible vapors.

B. Inorganic Vapors and Gases

The number of direct reading instruments with the capability to detect and quantify nonspecific inorganic vapors and gases is extremely limited. Presently, the HNU photoionizer has very limited detection capability while the Foxboro OVA has none. (See Appendix I for characteristics). If specific inorganics are known or suspected to be present, measurements should be made with appropriate instruments, if available. Colorimetric tubes are only practical if substances present are known or can be narrowed to a few.

C. Radiation

Although radiation monitoring is not necessary for all responses, it should be incorporated in the initial survey where radioactive materials may be present - for example, fires at warehouses or hazardous material storage facilities, transportation incidents involving unknown materials, or abandoned waste sites.

Normal background exposure-rate for gamma radiation is approximately 0.01 to 0.02 milliroentgen per hour (mR/hr) on a gamma survey instrument. Work can continue with elevated radiation-exposure rates; however, if the exposure-rate increases to 3-5 times above gamma background, a qualified health physicist should be consulted. At no time should work continue with an exposure rate of 10 mR/hr or above without the advice of a health physicist. EPA's Office of Air, Noise and Radiation has radiation specialists in each Region, as well as at Headquarters, Montgomery, Alabama, and Las Vegas, Nevada, to assist. The absence of gamma readings above background should not be interpreted as the complete absence of radioactivity. Radioactive materials emitting low-energy gam-

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*The use of any trade names does not imply their endorsement by the U.S. Environmental Protection Agency.

ma, alpha, or beta radiation may be present, but for a number of reasons may not cause a response on the instrument. Unless airborne, these radioactive materials should present minimal hazard, but more thorough surveys should be conducted as site operations continue to completely rule out the presence of any radioactive material.

D. Oxygen Deficiency

Normal air contains about 20.5% by volume of oxygen. At or below 19.5% oxygen air-supplied respiratory protective equipment is needed. Oxygen measurements are of particular importance for work in enclosed spaces, low-lying areas, or in the vicinity of accidents that have produced heavier-than-air vapors which could displace ambient air. These oxygen deficient areas are also prime locations for taking further organic vapor and combustible gas measurements, since the air has been displaced by other substances. Oxygen-enriched atmospheres increase the potential for fires.

E. Combustible Gases

The presence or absence of combustible vapors or gases must be determined. If readings approach or exceed 10% of the lower explosive limit (LEL), extreme caution should be exercised in continuing the investigation. If readings approach or exceed 25% LEL, personnel should be withdrawn immediately. Before resuming any on-site activities, project personnel in consultation with experts in fire or explosion prevention must develop procedures for continuing operations.

F. Visual Observations

While on-site, the initial entry team should make visual observations which would help in evaluating site hazards, for example, dead fish or other animals; land features; wind direction; labels on containers indicating explosive, flammable, toxic, or corrosive materials; conditions conducive to splash or contact with unconfined liquids, sludges, or solids; and other general conditions.

G. Direct-Reading Instruments

A variety of toxic air pollutants, (including organic and inorganic vapors, gases, or particulates) can be produced at, for example, abandoned waste sites; fires at chemical manufacturing, storage, reprocessing, or formulating facilities; or fires involving pesticides. Direct-reading field instruments will not detect or measure all of these substances. Thus, negative readings should not be interpreted as the complete absence of airborne toxic substances. Verification of negative results can only be done by collecting air samples and analyzing them in a laboratory.

III. OTHER CONSIDERATIONS

A. Initial Surveys

In general, the initial entry is considered a relatively rapid screening process for collecting preliminary data on site hazards.

The time needed to conduct the initial survey depends on the urgency of the situation, type of incident, information needed, size of site, availability of resources, and Level of Protection required for initial entry personnel. Consequently, initial surveys may need hours or days to complete and consist of more than one entry.

B. Priority for Initial Entry Monitoring

Of immediate concern to initial entry personnel are atmospheric conditions which could affect their immediate safety. These conditions are airborne toxic substances, combustible gases or vapors, lack of oxygen, and to a lesser extent, ionizing radiation. Priorities for monitoring these potential hazards should be established after a careful evaluation of conditions.

When the type of material involved in an incident is identified and its release into the environment suspected or known, the material's chemical/physical properties and the prevailing weather conditions may help determine the order of monitoring. An unknown substance or situation presents a more difficult monitoring problem.

In general, for poorly ventilated spaces - buildings, ship's holds, boxcars, or bulk tanks - which must be entered, combustible vapors/gases and oxygen-deficient atmospheres should be monitored first with team members wearing, as a minimum, Level B protective equipment (Levels of Protection are described in Part 5). Toxic gases/vapors and radiation, unless known not to be present, should be measured next.

For open, well-ventilated areas, combustible gases and oxygen deficiency are lesser hazards, and require lower priority.
However, areas of lower elevation on-site (such as ditches and gulleys) and downwind areas may have combustible gas mixtures, in addition to toxic vapors or gases, and lack sufficient oxygen to sustain life. Entry teams should approach and monitor whenever possible from the upwind area.

C. Periodic Monitoring

The monitoring surveys made during the initial site entry phase are for a preliminary evaluation of atmospheric hazards. In some situations, the information obtained may be sufficient to preclude additional monitoring - for example, a chlorine tank determined to be releasing no chlorine. Materials detected during the initial site survey call for a more comprehensive evaluation of

hazards and analyses for specific components. A program must be established for monitoring, sampling, and evaluating hazards for the duration of site operations. Since site activities and weather conditions change, a continuous program to monitor atmospheric changes must be implemented utilizing a combination of stationary sampling equipment, personal monitoring devices, and periodic area monitoring with direct-reading instruments.

D. Off-Site Monitoring and Sampling

Whenever possible, atmospheric hazards in the areas adjacent to the on-site zone should be monitored with direct-reading instruments, and air samples should be taken before the initial entry for on-site investigations. Negative instrument readings off-site should not be construed as definite indications of on-site conditions, but only another piece of information to assist in the preliminary evaluation.

E. Monitoring Instruments

It is imperative that personnel using monitoring instruments be thoroughly familiar with their use, limitations, and operating characteristics. All instruments have inherent constraints in their ability to detect and/or quantify the hazards for which they were designed. Unless trained personnel use instruments and assess data readout, air hazards can be grossly misinterpreted, endangering the health and safety of response personnel. In addition, only instruments approved for use in hazardous locations should be used, unless combustible gases or vapors are absent.

F. Ambient Atmospheric Concentrations

Any indication of atmospheric hazards - toxic substances, combustible gases, lack of oxygen, and radiation should be viewed as a sign to proceed with care and deliberation. Readings indicating nonexplosive atmospheres, low concentrations of toxic substances, or other conditions may increase or decrease suddenly, changing the associated risks. Extreme caution should be exercised in continuing surveys when any atmospheric hazards are indicated.

TABLE 4-1

ATMOSPHERIC HAZARD GUIDELINES

Monitoring Equipment	Hazard	Ambient Level	Action
Combustible gas indicator	Explosive atmosphere	< 10% LEL	Continue investigation with cautions.
		10%-25%	Continue on-site monitoring with extreme caution as higher levels are encountered.
		> 25% LEL	Explosion hazard; withdraw from area immediately.
Oxygen concentration meter	Oxygen	< 19.5%	Monitor wearing SCBA. NOTE: Combustible gas readings are not valid in atmospheres with < 19.5% oxygen.
		19.5%-25%	Continue investigation with caution. SCBA not needed, based on oxygen content only.
		> 25.0%	Discontinue inspection; fire hazard potential. Consult specialist.
Radiation survey	Radiation	< 1 mR/hr	Continue investigation. If radiation is detected above background levels, this signifies the presence of possible radiation sources; at this level, more thorough monitoring is advisable. Consult with a health physicist.
		> 10 mR/hr	Potential radiation hazard; evacuate site. Continue monitoring only upon the advice of a health physicist.

TABLE 4-1 (Cont'd.)

Monitoring Equipment	Hazard	Ambient Level	Action
Colorimetric tubes	Organic and inorganic vapors/gases	Depends on chemical	Consult standard reference manual for air concentrations/ toxicity data.
Photoionization detector (PID)	Organic vapors/gases	1) Depends on species	Consult standard reference manuals for air concentrations/ toxicity data.
		2) Total response mode	Consult EPA Standard Operating Safety Guides.
Flame ionization detector (FID)	vapor/gses	1) Depends on chemical	Consult standard reference manuals for air concentrations/toxicity data.
		2) Total response mode	Consult EPA Standard Operating Safety Guides.

PART 5

SITE ENTRY - LEVELS OF PROTECTION

I. INTRODUCTION

Personnel must wear protective equipment when response activities involve known or suspected atmospheric contamination, when vapors, gases, or particulates may be generated by site activities, or when direct contact with skin-affecting substances may occur. Full face-piece respirators protect lungs, gastrointestinal tract, and eyes against airborne toxicants. Chemical-resistant clothing protects the skin from contact with skin-destructive and -absorbable chemicals. Good personal hygiene limits or prevents ingestion of material.

Equipment to protect the body against contact with known or anticipated toxic chemicals has been divided into four categories according to the degree of protection afforded:

- Level A: Should be worn when the highest level of respiratory, skin, and eye protection is needed.
- Level B: Should be worn when the highest level of respiratory protection is needed, but a lesser level of skin protection.
- Level C: Should be worn when the criteria for using air-purifying respirators are met.
- Level D: Should be worn only as a work uniform and not on any site with respiratory or skin hazards. It provides no protection against chemical hazards.

The Level of Protection selected should be based on:

- Type and measured concentration of the chemical substance in the ambient atmosphere and its toxicity.
- Potential for exposure to substances in air, splashes of liquids, or other direct contact with material due to work being done.

In situations where the type of chemical, concentration, and possibilities of contact are not known, the appropriate Level of Protection must be selected based on professional experience and judgment until the hazards can be better identified.

While personnel protective equipment reduces the potential for contact with toxic substances, ensuring the health and safety of responders requires, in addition, safe work practices, decontamination, site entry protocols, and other safety procedures. Together, these provide an integrated approach for reducing harm to workers.

II. LEVELS OF PROTECTION

A. Level A Protection

1. Personnel protective equipment

   - Supplied-air respirator approved by the Mine Safety and Health Administration (MSHA) and National Institute for Occupational Safety and Health (NIOSH). Respirators may be:

     -- pressure-demand, self-contained breathing apparatus (SCBA)

     or

     -- pressure-demand, airline respirator (with escape bottle for Immediately Dangerous to Life and Health (IDLH) or potential for IDLH atmosphere)

   - Fully encapsulating chemical-resistant suit
   - Coveralls*
   - Long cotton underwear*
   - Gloves (inner), chemical-resistant
   - Boots, chemical-resistant, steel toe and shank. (Depending on suit construction, worn over or under suit boot)
   - Hard hat* (under suit)
   - Disposable gloves and boot covers* (Worn over fully encapsulating suit)
   - Cooling unit*
   - 2-Way radio communications* (inherently safe)

2. Criteria for selection

   Meeting any of these criteria warrants use of Level A Protection:

   - The chemical substance has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on:

     -- measured (or potential for) high concentration of

*Optional

atmospheric vapors, gases, or particulates

or

-- site operations and work functions involves high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials highly toxic to the skin.

- Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible.

- Operations must be conducted in confined, poorly ventilated areas until the absence of substances requiring Level A protection is determined.

- Direct readings on field Flame Ionization Dectors (FID) or Photoionization Detectors (PID) and similar instruments indicate high levels of unidentified vapors and gases in the air. (See Appendixes I and II.)

3. Guidance on selection

a. Fully encapsulating suits are primarily designed to provide a gas or vapor tight barrier between the wearer and atmospheric contaminants. Therefore Level A is generally worn when high concentrations of airborne substances are known or thought to be present and these substances could severely effect the skin. Since Level A requires the use of a self-contained breathing apparatus, the eyes and respiratory system are also more protected.

Until air surveillance data are available to assist in the selection of the appropriate Level of Protection, the use of Level A may have to be based on indirect evidence of the potential for atmospheric contamination or other means of skin contact with severe skin affecting substances.

Conditions that may require Level A protection include:

- Confined spaces: Enclosed, confined, or poorly ventilated areas are conducive to build up of toxic vapors, gases, or particulates. (Explosive or oxygen-deficient atmospheres also are more probable in confined spaces.) Confined space entry does not automatically warrant wearing Level A protection, but should serve as a cue to carefully consider and to justify a lower Level of Protection.

- Suspected/known highly toxic substances: Various substances that are highly toxic especially through skin absorption for example, fuming corrosives, cyanide compounds, concentrated pesticides, Department of Transportation Poison "A" materials, suspected carcinogens, and infectious substances may be known or suspected to be involved. Field instruments may not be available to detect or quantify air concentrations of these materials. Until these substances are identified and concentrations measured, maximum protection may be necessary.

- Visible emissions: Visible air emissions from leaking containers or railroad/vehicular tank cars, as well as smoke from chemical fires and others, indicate high potential for concentrations of substances that could be extreme respiratory or skin hazards.

- Job functions: Initial site entries are generally walk-throughs in which instruments and visual observations are used to make a preliminary evaluation of the hazards. In initial site entries, Level A should be worn when:

  -- there is a probability for exposure to high concentrations of vapors, gases, or particulates.

  -- substances are known or suspected of being extremely toxic directly to the skin or by being absorbed.

Subsequent entries are to conduct the many activities needed to reduce the environmental impact of the incident. Levels of Protection for later operations are based not only on data obtained from the initial and subsequent environmental monitoring, but also on the probability of contamination and ease of decontamination.

Examples of situations where Level A has been worn are:

- Excavating of soil to sample buried drums suspected of containing high concentrations of dioxin.

- Entering a cloud of chlorine to repair a value broken in a railroad accident.

- Handling and moving drums known to contain oleum.

- Responding to accidents involving cyanide, arsenic, and undiluted pesticides.

b. The fully encapsulating suit provides the highest degree of protection to skin, eyes, and respiratory system if the suit material resists chemicals during the time the suit is worn. While Level A provides maximum protection, all suit material may be rapidly permeated and degraded by certain chemicals from extremely high air concentrations, splashes, or immersion of boots or gloves in concentrated liquids or sludges. These limitations should be recognized when specifying the type of fully encapsulating suit. Whenever possible, the suit material should be matched with the substance it is used to protect against.

B. Level B Protection

1. Personnel protective equipment

- Supplied-air respirator (MSHA/NIOSH approved). Respirators may be:

  -- pressure-demand, self-contained breathing apparatus

  or

  -- pressure-demand, airline respirator (with escape bottle for IDLH, or potential for IDLH, atmosphere)

- Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one or two-piece chemical-splash suit; disposable chemical-resistant, one-piece suits)

- Long cotton underwear*

- Coveralls*

- Gloves (outer), chemical-resistant

- Gloves (inner), chemical-resistant

- Boots (outer), chemical-resistant, steel toe and shank

- Boot covers (outer), chemical-resistant (disposable)*

- Hard hat (face shield)*

- 2-Way radio communications* (intrinsically safe)

2. Criteria for selection

Meeting any one of these criteria warrants use of Level B protection:

- The type and atmospheric concentration of toxic substances has been identified and requires a high level of respiratory protection, but less skin protection than Level A. These would be atmospheres:

*Optional

    - with concentrations Immediately Dangerous to Life and Health, but substance or concentration in the air does not represent a severe skin hazard

or

    - that do not meet the selection criteria permitting the use of air-purifying respirators.

- The atmosphere contains less than 19.5% oxygen.
- It is highly unlikely that the work being done will generate high concentrations of vapors, gases or particulates, or splashes of material that will affect the skin of personnel wearing Level B protection.
- Atmospheric concentrations of unidentified vapors or gases are indicated by direct readings on instruments such as the FID or PID or similar instruments, but vapors and gases are not suspected of containing high levels of chemicals toxic to skin. (See Appendixes I and II.)

3. Guidance on selection

a. Level B does not afford the maximum skin (and eye) protection as does a fully encapsulating suit since the chemical-resistant clothing is not considered gas, vapor, or particulate tight. However, a good quality, hooded, chemical-resistant, one-piece garment, with taped wrist, ankles, and hood does provides a reasonable degree of protection against splashes and to lower concentrations in air. At most abandoned hazardous waste sites, ambient atmospheric gas or vapor levels have not approached concentrations sufficiently high to warrant Level A protection. In all but a few circumstances (where highly toxic materials are suspected) Level B should provide the protection needed for initial entry. Subsequent operations at a site require a reevaluation of Level B protection based on the probability of being splashed by chemicals, their effect on the skin, the presence of hard-to-detect air contaiminants, or the generation of highly toxic gases, vapors, or particulates, due to the work being done.

b. The chemical-resistant clothing required in Level B is available in a wide variety of styles, materials, construction detail, and permeability. One or two-piece garments are available with or without hoods. Disposal suits with a variety of fabrics and design characteristics are also available. Taping joints between the gloves, boots and suit, and between hood and respirator reduces the possiblity for splash and vapor or gas penetration. These factors and other selection criteria all affect the degree of protection afforded. Therefore, a specialist should select the most effective chemical-resistant clothing based on the known or anticipated hazards and job function.

Level B equipment does provides a high level of protection to the respiratory tract. Generally, if a self-contained breathing apparatus is required for respiratory protection, selecting chemical-resistant clothing (Level B) rather than a fully encapsulating suit (Level A) is based on needing less protection against known or anticipated substances affecting the skin. Level B skin protection is selected by:

- Comparing the concentrations of known or identified substances in air with skin toxicity data.

- Determining the presence of substances that are destructive to or readily absorbed through the skin by liquid splashes, unexpected high levels of gases, vapor, or particulates, or other means of direct contact.

- Assessing the effect of the substance (at its measured air concentrations or potential for splashing) on the small areas left unprotected by chemical-resistant clothing. A hooded garment taped to the mask, and boots and gloves taped to the suit further reduces area of exposure.

c. For initial site entry and reconnaissance at an open site, approaching whenever possible from upwind, Level B protection (with good quality, hooded, chemical-resistant clothing) should protect response personnel, providing the conditions described in selecting Level A are known or judged to be absent.

C. Level C Protection

1. Personnel protective equipment

- Air-purifying respirator, full-face, canister-equipped (MSHA/NIOSH approved)

- Chemical-resistant clothing (coveralls; hooded, one-piece or two-piece chemical splash suit; chemical-resistant hood and apron; disposable chemical-resistant coveralls)

- Coveralls*

- Long cotton underwear*

- Gloves (outer), chemical-resistant

- Gloves (inner), chemical-resistant*
- Boots (outer), chemical-resistant, steel toe and shank
- Boot covers (outer), chemical-resistant (disposable)*
- Hard hat (face shield*)
- Escape mask*
- 2-Way radio communications* (inherently safe)

2. Criteria for selection

Meeting all of these criteria permits use of Level C protection:

- Oxygen concentrations are not less than 19.5% by volume.
- Measured air concentrations of identified substances will be reduced by the respirator below the substance's threshold limit value (TLV) and the concentration is within the service limit of the canister.
- Atmospheric contaminant concentrations do not exceed IDLH levels.
- Atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any body area left unprotected by chemical-resistant clothing.
- Job functions do not require self-contained breathing apparatus.
- Direct readings are a few ppms above background on instruments such as the FID or PID. (See Appendices I and II.)

3. Guidance on selection

a. Level C protection is distinguished from Level B by the equipment used to protect the respiratory system, assuming the same type of chemical-resistant clothing is used. The main selection criterion for Level C is that conditions permit wearing air-purifying respirators.

The air-purifying device must be a full-face respirator (MSHA/NIOSH approved) equipped with a canister suspended from the chin or on a harness. Canisters must be able to

*Optional

remove the substances encountered. Quarter-or half-masks or cheekcartridge, full-face masks should be used only with the approval of a qualified individual.

In addition, a full-face, air-purifying mask can be used only if:

- Substance has adequate warning properties.
- Individual passes a qualitative fit-test for the mask.
- Appropriate cartridge/canister is used, and its service limit concentration is not exceeded.

b. An air surveillance program is part of all response operations when atmospheric contamination is known or suspected. It is particularly important that the air be thoroughly monitored when personnel are wearing air-purifying respirators.

Periodic surveillance using direct-reading instruments and air sampling is needed to detect any changes in air quality necessitating a higher level of respiratory protection.

c. Level C protection with a full-face, air-purifying respirator should be worn routinely in an atmosphere only after the type of air contaminant is identified, concentrations measured and the criteria for wearing air-purifying respirator met. To permit flexibility in precribing a Level of Protection at certain environmental incidents, a specialist could consider using air-purifying respirators in unidentified vapor/gas concentrations of a few parts per million above background as indicated by a needle deflection on the FID or PID. However a needle deflection of a few parts per million above background should not be the sole criterion for selecting Level C. Since the individual components may never be completely identified, a decision on continuous wearing of Level C must be made after assessing all safety considerations, including:

- The presence of (or potential for) organic or inorganic vapors/gases against which a canister is ineffective or has a short service life.
- The known (or suspected) presence in air of substances with low TLVs or IDLH levels.
- The presence of particulates in air.
- The errors associated with both the instruments and monitoring

*Optional

procedures used.

- The presence of (or potential for) substances in air which do not elicit a response on the instrument used.

- The potential for higher concentrations in the ambient atmosphere or in the air adjacent to specific site operations.

d. The continuous use of air-purifying respirators (Level C) must be based on the identification of the substances contributing to the total vapor or gas concentration and the application of published criteria for the routine use of air-purifying devices. Unidentified ambient concentrations of organic vapors or gases in air approaching or exceeding a few ppm above background require, as a minimum, Level B protection.

D. Level D Protection

1. Personnel protective equipment
   - Coveralls
   - Gloves*
   - Boots/shoes, leather or chemical-resistant, steel toe and shank
   - Safety glasses or chemical splash goggles*
   - Hard hat (face shield)*

2. Criteria for selection

Meeting any of these criteria allows use of Level D protection:

- No contaminants are present.

- Work functions preclude splashes, immersion, or potential for unexpected inhalation of any chemicals.

Level D protection is primarily a work uniform. It can be worn only in areas where there is no possibility of contact with contamination.

III. PROTECTION IN UNKNOWN ENVIRONMENTS

In all incident response, selecting the appropriate personnel protection equipment is one of the first steps in reducing health effects from toxic substances. Until the toxics hazards at an environmental incident can be identified and personnel safety measures commensurate with the hazards instituted, preliminary measures will have to be based on experience, judgment, and professional knowledge. One of the first concerns in evaluating an unknown situation is atmospheric hazards. Toxic concentrations (or potential concentrations) of vapors, gases, and particulates; low oxygen content explosive potential and, to a lesser degree, the possibility of radiation exposure all represent immediate atmospheric hazards. In addition to making air measurements to determine these hazards, visual observation and review of existing data can help determine the potential risks from other materials.

Once immediate hazards, other than toxic substances have been eliminated, the initial on-site survey and reconnaissance, which may consist of more than one entry, continues. Its purpose is to further characterize toxic hazards and, based on these findings, refine preliminary safety requirements. As data are obtained from the initial survey, the Level of Protection and other safety procedures are adjusted. Initial data also provide information on which to base further monitoring and sampling. No one method can determine a Level of Protection in all unknown environments. Each situation must be examined individually.

IV. ADDITIONAL CONSIDERATIONS FOR SELECTING LEVELS OF PROTECTION

Other factors which should be considered in selecting the appropriate Level of Protection are:

A. Heat and Physical Stress

The use of protective clothing and respirators increases physical stress, in particular heat stress, on the wearer. Chemicalprotective clothing greatly reduces body ventilation and diminishes its ability to regulate its temperature. Even in moderate ambient temperatures the diminished capacity of the body to dissipate heat can result in one or more heat-related problems.

All chemical protective garments can cause heat stress. Somewhat less stress is associated with Level B or C when the protective clothing does not require the use of a hood, tightly fitted against the respirator face piece, and taped glove, boot, suit interfaces, since more body ventilation and evaporation may occur. As more body area is covered, the probability of heat stress increases. Whenever any chemical-protective clothing is worn, a heat stress recovery monitoring program must occur (see Part 3, Section V).

Wearing protective equipment also increases the risk of accidents. It is heavy, cumbersome, decreases dexterity, agility, interferes with vision, and is fatiguing to wear. These factors all increase physical stress and the potential of accidents. In particular the necessity for selecting Level A protection, should be balanced against the increased probability of physical stress and accidents. Level B and C protection somewhat reduces accident probability, because the equipment is lighter, less cumbersome, and vision problems less serious.

B. Air Surveillance

A program must be established for routine, periodic air surveillance. Without an air surveillance program, any changes could go undetected and jeopardize response personnel. Surveillance can be accomplished with various types of air pumps and filtering devices followed by analysis of the filtering media; portable real-time monitoring instruments located strategically on-site; personal dosimeters; and periodic walk-throughs by personnel carrying direct-reading instruments. (See Part 8)

C. Decision - Logic for Selecting Protective Clothing

No adequate criteria, similar to the respiratory protection decision-logic, are available for selecting protective clothing. A concentration of a known substance in the air approaching a TLV or permissible exposure limit for the skin does not automatically warrant a fully encapsulating suit. A hooded, high quality, chemical-resistant suit may provide adequate protection. The selection of Level A over Level B is a judgment that should be made by a qualified individual considering the following factors:

- The physical form of the potential contaminant. Airborne substances are more likely for body contact with personnel wearing non-encapsulating suits, since they are not considered to be gas or vapor tight.

- Effect of the material on skin:

    -- highly hazardous substances are those that are easily absorbed through the skin causing systemic effects, or that cause severe skin destruction. Skin contact with liquids are generally more hazardous than vapors, gases and particulates.

    -- less hazardous substances are those that are not easily absorbed through the skin causing systemic effects, or that do not cause severe skin destruction

- Concentration of the material - the higher the concentration, the higher the risk of harm.

- The potential for contact with the material due to work function and the probability of direct exposure to the small area of skin unprotected by Level B or C chemical-resistant clothing.

D. Chemicals Toxic to Skin

The chemicals listed in Appendix III are identified in the Oil and Hazardous Materials Technical Assistance Data Base System (OHMTADS) as having adverse skin effects ranging from irritation to absorption into the body. Knowledge concerning the presence or absence of these materials could be useful in selecting the necessary Level of Protection. Other substances affecting the skin, but not listed in OHMTADS, may be present. Therefore, a major effort should be made to identify all substances.

E. Atmospheric Conditions

Atmospheric conditions such as stability, temperature, wind direction, wind velocity, and barometric pressure determine the behavior of contaminants in air or the potential for volatile material getting into air. These parameters should be considered in determining the need for and Level of Protection required.

F. Work in Exclusion Zone

For operations in the Exclusion Zone (area of potential contamination), different Levels of Protection may be selected, and various types of chemical-resistant clothing worn. This selection would be based not only on measured air concentrations, but also on the job function, reason for being in the area, the potential for skin contact or inhalation of the materials present, and ability to decontaminate the protective equipment used. (See Part 6)

G. Escape Masks

The use of escape masks is an option in Level C protection. A specialist should determine their use on a case-by-case basis. Escape masks could also be strategically located on-site in areas that have higher possibilities for harmful exposure.

V. VAPOR OR GAS CONCENTRATIONS AS INDICATED BY DIRECT-READING INSTRUMENTS

Instruments such as the FID and PID can be used to detect the presence of many organic vapors or gases either as single compounds or mixtures. Dial readings are frequently referred to, especially with unidentified substances, as total vapor and gas concentrations (in ppm). More correctly they are deflections of the needle on the dial indicating an instrument response and does not directly relate to total concentration in the air. As a guide to selecting Level of Protections, based on dial readings response, the following values could be used. They should not be the sole criteria for selecting Levels of Protection.

Dial Reading	Level of Protection
Background to 5 ppm above background	C
5 ppm above background to 500 ppm	B
500 ppm above background to 1000 ppm	A

Vapor or gas concentration, as indicated by the readout on instruments such as the FIDs or PIDs are a useful adjunct to professional judgment in selecting the Level of Protection to be worn in an unknown environment. It should not be the single selection criterion, but should be considered with all other available information. Total vapor or gas concentration as selection criteria for Levels of Protection should only by used by qualified persons thoroughly familiar with the information contained in Appendices I and II.

PART 6

SITE CONTROL - WORK ZONES

I. INTRODUCTION

The activities required during responses to incidents involving hazardous substances may contribute to the unwanted movement of contaminants from the site to uncontaminated areas. Response personnel and equipment may become contaminated and transfer the material into clean areas. Material may become airborne due to its volatility or the disturbance of contaminated soil may cause it to become windblown. To minimize the transfer of hazardous substances from the site, contamination control procedures are needed. Two general methods are used: establishing site work zones (discussed here) and removing contaminants from people and equipment (discussed in Part 7).

II. CONTROL AT THE SITE

A site must be controlled to reduce the possibility of: 1) contact with any contaminants present and 2) removal of contaminants by personnel or equipment leaving the site. The possibility of exposure or translocation of substances can be reduced or eliminated in a number of ways, including:

- Setting up security and physical barriers to exclude unnecessary personnel from the general area.
- Minimizing the number of personnel and equipment on-site consistent with effective operations.
- Establishing work zones within the site.
- Establishing control points to regulate access to work zones.
- Conducting operations in a manner to reduce the exposure of personnel and equipment and to eliminate the potential for airborne dispersion.
- Implementing appropriate decontamination procedures.

III. WORK ZONES

One method of preventing or reducing the migration of contaminants is to delineate zones on the site in which prescribed operations occur. Movement of personnel and equipment between zones and onto the site

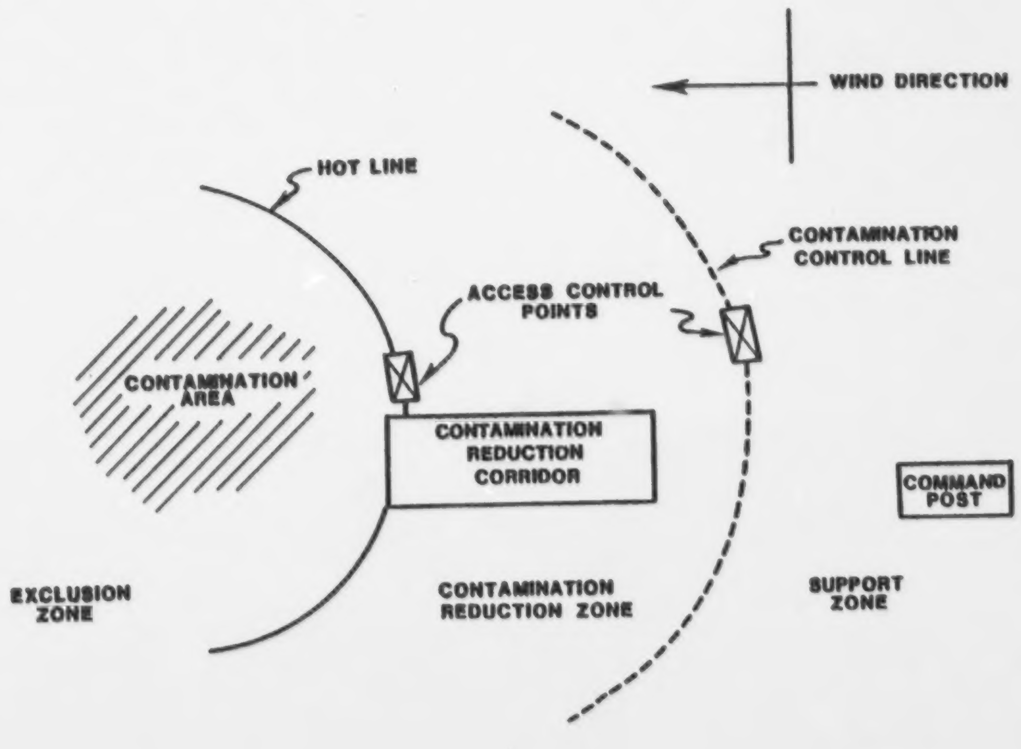


DIAGRAM OF SITE WORK ZONES

FIGURE 6-1

itself would be limited by access control points. By these means, Three contiguous zones (Figure 6-1) are recommended:

- Zone 1: Exclusion Zone

- Zone 2: Contamination Reduction Zone

- Zone 3: Support Zone

A. Zone 1: Exclusion Zone

The Exclusion Zone, the innermost of three areas, is the zone where contamination does or could occur. All people entering the Exclusion Zone must wear prescribed Levels of Protection. An entry and exit check point must be established at the periphery of the Exclusion Zone to regulate the flow of personnel and equipment into and out of the zone and to verify that the procedures established to enter and exit are followed.

The outer boundary of Zone 1, the Hotline, is initially established by visually surveying the immediate environs of the incident and determining where the hazardous substances involved are located; where any drainage, leachate, or spilled material is; and whether any discolorations are visible. Guidance in determining the boundaries is also provided by data from the initial site survey indicating the presence of organic or inorganic vapors/gases or particulates in air, combustible gases, and radiation, or the results of water and soil sampling.

Additional factors that should be considered include the distances needed to prevent fire or an explosion from affecting personnel outside the zone, the physical area necessary to conduct site operations, and the potential for contaminants to be blown from the area. Once the Hotline has been determined it should be physically secured, fenced, or well-defined by landmarks. During subsequent site operations, the boundary may be modified and adjusted as more information becomes available.

B. Subareas Within the Exclusion Zone

All personnel within the Exclusion Zone must wear the required Level of Protection. Personnel protective equipment is designated based on site-specific conditions including the type of work to be done and the hazards that might be encountered. Frequently within the Exclusion Zone, different Levels of Protection are justified. Subareas are specified and conspicuously marked as to whether Level A, B, or C protection is required (Figure 6-2). The Level of Protection is determined by the measured concentration of substances in air, potential for contamination, and the known or suspected presence of highly toxic substances.

Different Levels of Protection in the Exclusion Zone might also be designated by job assignment. For example, collecting samples from open containers might require Level B protection, while for walk-through ambient air monitoring, Level C protection might be sufficient. The assignment, when appropriate, of different Levels of Protection within the Exclusion Zone generally makes for a more flexible, effective, and less costly operation while still maintaining a high degree of safety.

C. Zone 3: Support Zone

The Support Zone, the outermost part of the site, is considered a noncontaminated or clean area. Support equipment (command post, equipment trailer, etc.) is located in the zone; traffic is restricted to authorized response personnel. Since normal work clothes are appropriate within this zone, potentially contaminated personnel clothing, equipment, and samples are not permitted, but are left in the Contamination Reduction Zone until they are decontaminated.

The location of the command post and other support facilities in the Support Zone depends on a number of factors, including:

- Accessibility: topography; open space available; locations of highways, railroad tracks; or other limitations.
- Wind direction: preferably the support facilities should be located upwind of the Exclusion Zone. However, shifts in wind direction and other conditions may be such that an ideal location based on wind direction alone does not exist.
- Resources: adequate roads, power lines, water, and shelter.

D. Zone 2: Contamination Reduction Zone

Between the Exclusion Zone and the Support Zone is the Contamination Reduction Zone which provides a transition between contaminated and clean zones. Zone 2 serves as a buffer to further reduce the probability of the clean zone becoming contaminated or being affected by other existing hazards. It provides additional assurance that the physical transfer of contaminating substances on people, equipment, or in the air is limited through a combination of decontamination, distance between Exclusion and Support Zones, air dilution, zone restrictions, and work functions.

Initially, the Contamination Reduction Zone is considered to be a noncontaminated area. At the boundary between the Exclusion and Contamination Reduction Zones, Contmination Reduction Corridors (decontamination stations) are established, one for personnel and one for heavy equipment. Depending on the size of the operation, more than two corridors may be necessary. Exit from the

Exclusion Zone is through a Contamination Reduction Corridor. As operations proceed, the area around the decontamination station may become contaminated, but to a much lesser degree than the Exclusion Zone. On a relative basis, the amount of contaminants should decrease from the Hotline to the Support Zone due to the distance involved and the decontamination procedures used.

The boundary between the Support Zone and the Contamination Reduction Zone, the Contamination Control Line, separates the possibly low contamination area from the clean Support Zone. Access to the Contamination Reduction Zone from the Support Zone is through a control point. Personnel entering there would wear the prescribed personnel protective equipment, if required, for working in the Contamination Reduction Zone. Entering the Support Zone requires removal of any protective equipment worn in the Contamination Reduction Zone.

IV. OTHER CONSIDERATIONS

A. Modifications

The use of a three-zone system, access control points, and exacting decontamination procedures provides a reasonable assurance against the translocation of contaminating substances. This site control system is based on a worst case situation. Less stringent site control and decontamination procedures may be utilized if more definitive information is available on the types of substances involved and hazards they present. This information can be obtained through air monitoring, instrument survey and sampling, and technical data concerning the characteristics and behavior of material present.

B. Area Dimensions

The distance between the Hotline, Contamination Control Line, and command post and the size and shape of each zone have to be based on conditions specific to each site (Figures 6-2 and 6-3). Considerable judgment is needed to assure that the distances between zone boundaries are large enough to allow room for the necessary operations, provide adequate distances to prevent the spread of contaminants, and eliminate the possiblity of injury due to explosion or fire. Long-term operations would involve developing reasonable methods (for example, air surveillance, swipe testing, and visible deterioration) to determine if material is being transferred between zones and to assist in modifying site boundaries.

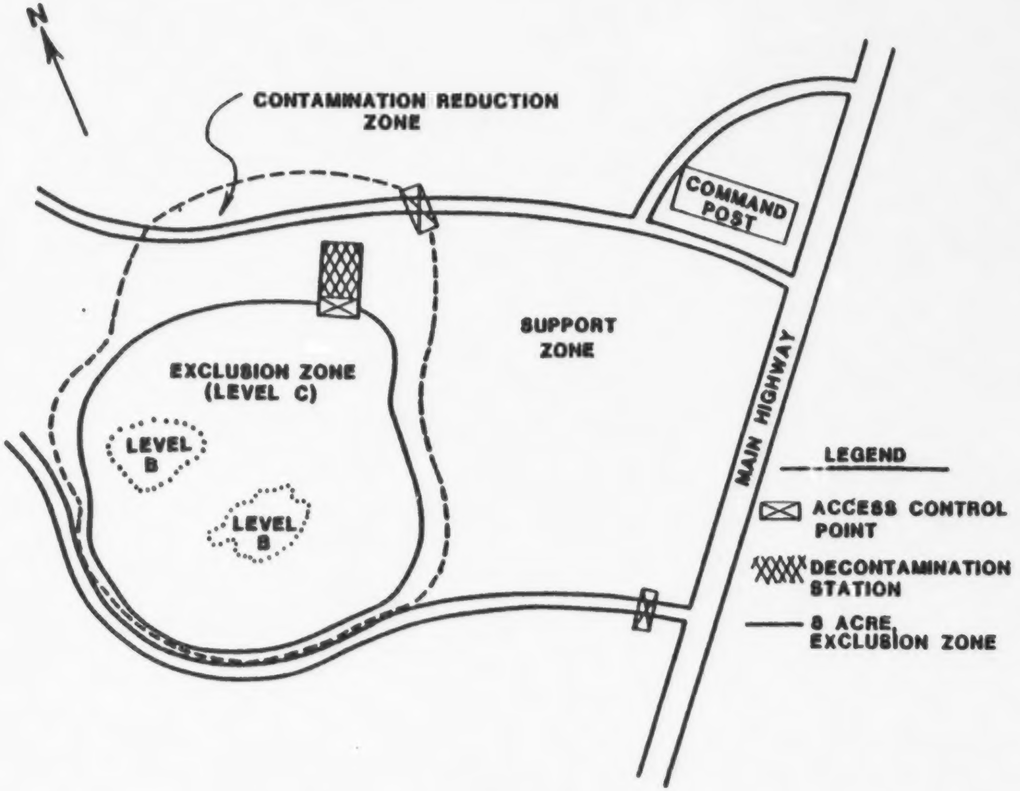
The following criteria should be considered in establishing area dimensions and boundaries:

- Physical and topographical features of the site.
- Weather conditions.
- Field/laboratory measurements of air contaminants and environmental samples.
- Air dispersion calculations.
- Potential for explosion and flying debris.
- Physical, chemical, toxicological, and other characteristics of the substances present.
- Cleanup activities required.
- Potential for fire.
- Area needed to conduct operations.
- Decontamination procedures.
- Potential for exposure.
- Proximity to residential or industrial areas.

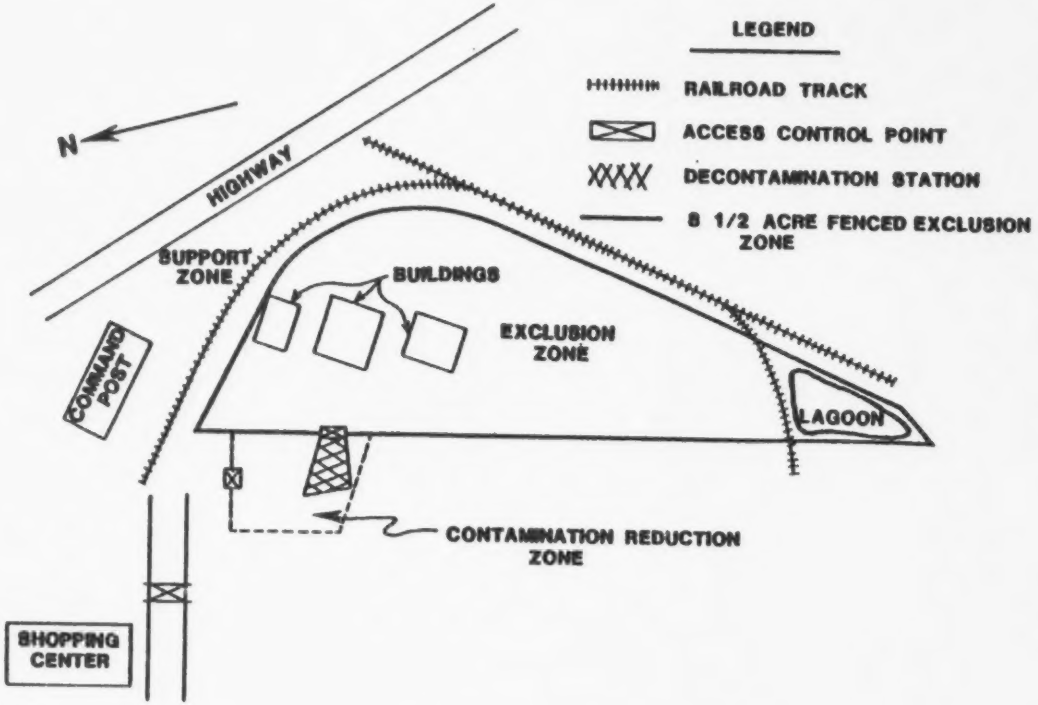
C. Monitoring and Sampling

To verify that site control procedures are preventing the spread of contamination, a monitoring and sampling program should be established. The Support Zone should be periodically monitored for air contaminants using direct-reading instruments and collecting air samples for particulate, gas, or vapor analysis. Analysis of soil samples collected in the most heavily trafficked area would indicate contaminants being carried from the Exclusion Zone by personnel, equipment, or wind. Occassional swipe tests should be taken in trailers and other areas used by personnel.

These same types of samples should be collected and air monitored in the Contamination Reduction Zone. Increased concentrations in air or other environmental media may indicate a breakdown in control over the Contamination Reduction Corridor, ineffective decontamination procedures, or failure to restrict site access.



NEW HAMPSHIRE WASTE SITE
FIGURE 6-2



LOCK HAVEN WASTE SITE
FIGURE 8-3

PART 7

SITE CONTROL - DECONTAMINATION

I. INTRODUCTION

Personnel responding to hazardous substance incidents may become contaminated in a number of ways including:

- Contacting vapors, gases, mists, or particulates in the air.
- Being splashed by materials while sampling or opening containers.
- Walking through puddles of liquids or on contaminated soil.
- Using contaminated instruments or equipment.

Protective clothing and respirators help prevent the wearer from becoming contaminated or inhaling contaminants; while good work practices help reduce contamination on protective clothing, instruments, and equipment.

Even with these safeguards, contamination may occur. Harmful materials can be transferred into clean areas, exposing unprotected personnel. In removing contaminated clothing, personnel may contact contaminants on the clothing or inhale them. To prevent such occurrences, methods to reduce contamination, and decontamination procedures must be developed and established before anyone enters a site and must continue (modified when necessary) throughout site operations.

Decontamination consists of physically removing contaminants or changing their chemical nature to innocuous substances. How extensive decontamination must be depends on a number of factors, the most important being the type of contaminants involved. The more harmful the contaminant, the more extensive and thorough decontamination must be. Less harmful contaminants may require less decontamination.

Combining decontamination, the correct method of doffing personnel protective equipment, and the use of site work zones minimizes cross-contamination from protective clothing to wearer, equipment to personnel, and one area to another. Only general guidance can be given on methods and techniques for decontamination. The exact procedure to use must be determined after evaluating a number of factors specific to the incident.

II. PRELIMINARY CONSIDERATIONS

A. Initial Planning

The initial decontamination plan assumes all personnel and equipment leaving the Exclusion Zone (area of potential contamination) are grossly contaminated. A system is then set up for personnel decontamination to wash and rinse, at least once, all the protective equipment worn. This is done in combination with a sequential doffing of protective equipment, starting at the first station with the most heavily contaminated item and progressing to the last station with the least contaminated article. Each piece precedure requires a separate station.

The spread of contaminants during the washing/doffing process is further reduced by separating each decontamination station by a minimum of 3 feet. Ideally, contamination should decrease as a person moves from one station to another further along in the line.

While planning site operations, methods should be developed to prevent the contamination of people and equipment. For example, using remote sampling techniques, not opening containers by hand, bagging monitoring instruments, using drum grapplers, watering down dusty areas, and not walking through areas of obvious contamination would reduce the probability of becoming contaminated and require a less elaborate decontamination procedure.

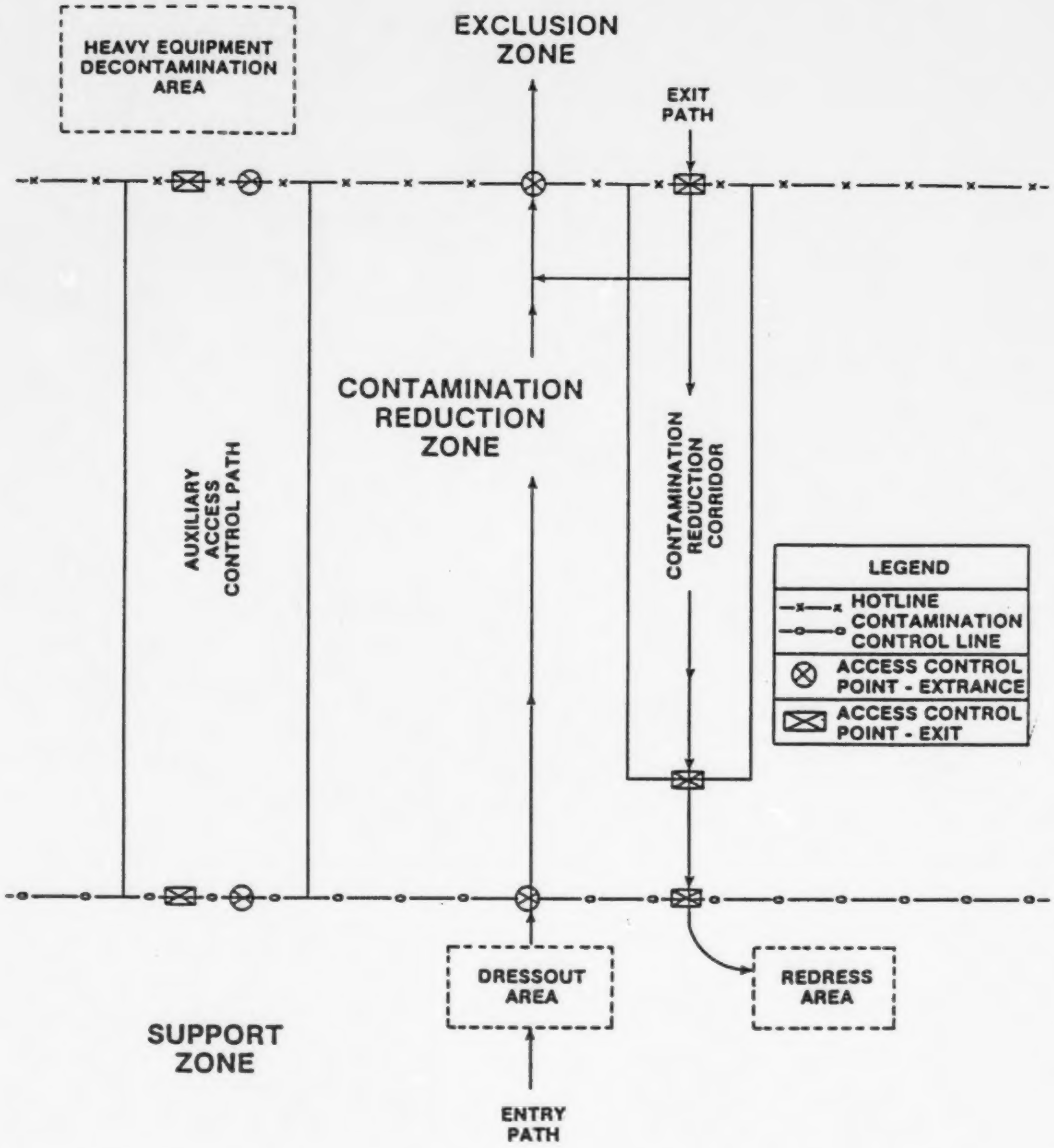
The initial decontamination plan is based on a worst-case situation or assumes no information is available about the incident. Specific conditions at the site are then evaluated, including:

- Type of contaminant.
- The amount of contamination.
- Levels of protection required.
- Type of protective clothing worn.

The initial decontamination plan is modified, eliminating unnecessary stations or otherwise adapting it to site conditions. For instance, the initial plan might require a complete wash and rinse of chemical protective garments. If disposable garments are worn, the wash/rinse step could be omitted. Wearing disposable boot covers and gloves could eliminate washing and rinsing these items and reduce the number of stations needed.

B. Contamination Reduction Corridor

An area within the Contamination Reduction Zone is designated the Contamination Reduction Corridor (CRC). The CRC controls access into and out of the Exclusion Zone and confines decontamination activities to a limited area. The size of the corridor depends on the number of stations in the decontamination procedure,


HEAVY EQUIPMENT DECONTAMINATION AREA
EXCLUSION ZONE
EXIT PATH
CONTAMINATION REDUCTION ZONE
AUXILIARY ACCESS CONTROL PATH
CONTAMINATION REDUCTION CORRIDOR
LEGEND
HOTLINE
CONTAMINATION CONTROL LINE
ACCESS CONTROL POINT - EXTRANCE
ACCESS CONTROL POINT - EXIT
DRESSOUT AREA
REDRESS AREA
SUPPORT ZONE
ENTRY PATH

CONTAMINATION REDUCTION ZONE LAYOUT
FIGURE 7-1

overall dimensions of work control zones, and amount of space available at the site. A corridor of 75 feet by 15 feet should be adequate for full decontamination. Whenever possible, it should be a straight path.

The CRC boundaries should be conspicuously marked, with entry and exit restricted. The far end is the hotline - the boundary between the Exclusion Zone and the Contamination Reduction Zone. Personnel exiting the Exclusion Zone must go through the CRC. Anyone in the CRC should be wearing the Level of Protection designated for the decontamination crew. Another corridor may be required for heavy equipment needing decontamination. Within the CRC, distinct areas are set aside for decontamination of personnel, portable field equipment, removed clothing, etc. These areas should be marked and personnel restricted to those wearing the appropriate Level of Protection. All activities within the corridor are confined to decontamination.

Personnel protective clothing, respirators, monitoring equipment, and sampling supplies are all maintained outside of the CRC. Personnel don their protective equipment away from the CRC and enter the Exclusion Zone through a separate access control point at the hotline.

III. EXTENT OF DECONTAMINATION REQUIRED

A. Modifications of Initial Plan

The original decontamination plan must be adapted to specific conditions found at incidents. These conditions may require more or less personnel decontamination than planned, depending on a number of factors.

1. Type of Contaminant

The extent of personnel decontamination depends on the effects the contaminants have on the body. Contaminants do not exhibit the same degree of toxicity (or other hazard). Whenever it is known or suspected that personnel can become contaminated with highly toxic or skin-destructive substances, a full decontamination procedure should be followed. If less hazardous materials are involved, the procedure can be downgraded.

2. Amount of Contamination

The amount of contamination on protective clothing is usually determined visually. If it is badly contaminated, a thorough decontamination is generally required. Gross material remaining on the protective clothing for any extended period of time may degrade or permeate it. This likelihood increases with higher air concentrations and greater amounts of liquid contamination. Gross contamination also increases the probability of personnel contact. Swipe tests may help determine the type and quantity of surface contaminants.

3. Level of Protection

The Level of Protection and specific pieces of clothing worn determine on a preliminary basis the layout of the decontamination line. Each Level of Protection incorporates different problems in decontamination and doffing of the equipment. For example: decontamination of the harness straps and backpack assembly of the self-contained breathing apparatus is difficult. A butyl rubber apron worn over the harness makes decontamination easier. Clothing variations and different Levels of Protection may require adding or deleting stations in the original decontamination procedure.

4. Work Function

The work each person does determines the potential for contact with hazardous materials. In turn, this dictates the layout of the decontamination line. For example, observers, photographers, operators of air samplers, or others in the Exclusion Zone performing tasks that will not bring them in contact with contaminants may not need to have their garments washed and rinsed. Others in the Exclusion Zone with a potential for direct contact with the hazardous material will require more thorough decontamination. Different decontamination lines could be set up for different job functions, or certain stations in a line could be omitted for personnel performing certain tasks.

5. Location of Contamination

Contamination on the upper areas of protective clothing poses a greater risk to the worker because volatile compounds may generate a hazardous breathing concentration both for the worker and for the decontamination personnel. There is also an increased probability of contact with skin when doffing the upper part of clothing.

6. Reason for Leaving Site

The reason for leaving the Exclusion Zone also determines the need and extent of decontamination. A worker leaving the Exclusion Zone to pick up or drop off tools or instruments and immediately returning may not require decontamination. A worker leaving to get a new air cylinder or to change a respirator or canister, however, may require some degree of decontamination. Individuals departing the CRC for a break, lunch, or at the end of day, must be thoroughly decontaminated.

B. Effectiveness of Decontamination

There is no method to immediately determine how effective decontamination is in removing contaminants. Discolorations, stains, corrosive effects, and substances adhering to objects may indicate contaminants have not been removed. However, observable effects only indicate surface contamination and not permeation (absorption) into clothing. Also many contaminants are not easily observed.

A method for determining effectiveness of surface decontamination is swipe testing. Cloth or paper patches - swipes - are wiped over predetermined surfaces of the suspect object and analyzed in a laboratory. Both the inner and outer surfaces of protective clothing should be swipe tested. Positive indications of both sets of swipes would indicate surface contamination has not been removed and substances have penetrated or permeated through the garment. Swipe tests can also be done on skin or inside clothing. Permeation of protective garments requires laboratory analysis of a piece of the material. Both swipe and permeation testing provide after-the-fact information. Along with visual observations, results of these tests can help evaluate the effectiveness of decontamination.

C. Equipment

Decontamination equipment, materials, and supplies are generally selected based on availability. Other considerations are ease of equipment decontamination or disposability. Most equipment and supplies can be easily procured. For example, soft-bristle scrub brushes or long-handle brushes are used to remove contaminants. Water in buckets or garden sprayers is used for rinsing. Large galvanized wash tubs or stock tanks can hold wash and rinse solutions. Children's wading pools can also be used. Large plastic garbage cans or other similar containers lined with plastic bags store contaminated clothing and equipment. Contaminated liquids can be stored temporarily in metal or plastic cans or drums. Other gear includes paper or cloth towels for drying protective clothing and equipment.

D. Decontamination Solution

Personnel protective equipment, sampling tools, and other equipment are usually decontaminated by scrubbing with detergent-water using a soft-bristle brush followed by rinsing with copious amounts of water. While this process may not be fully effective in removing some contaminants (or in a few cases, contaminants may react with water), it is a relatively safe option compared with using a chemical decontaminating solution. This requires that the contaminant be identified. A decon chemical is then needed that will change the contaminant into a less harmful substance. Especially troublesome are unknown substances or mixtures from a variety of known or unknown substances. The appropriate decontamination solution must be selected in consultation with an experienced chemist.

E. Establishment of Procedures

Once decontamination procedures have been established, all personnel requiring decontamination must be given precise instructions (and practice, if necessary). Compliance must be frequently checked. The time it takes for decontamination must be ascertained. Personnel wearing SCBA's must leave their work area with sufficient air to walk to CRC and go through decontamination.

IV. DECONTAMINATION DURING MEDICAL EMERGENCIES

A. Basic Considerations

Part of overall planning for incident response is managing medical emergencies. The plan should provide for:

- Some response team members fully trained in first aid and CPR.
- Arrangements with the nearest medical facility for transportation and treatment of injured, and for treatment of personnel suffering from exposure to chemicals.
- Consultation services with a toxicologist.
- Emergency eye washes, showers, and/or wash stations.
- First aid kits, blankets, stretcher, and resuscitator.

In addition, the plan should establish methods for decontaminating personnel with medical problems and injuries. There is the possibility that the decontamination may aggravate or cause more serious health effects. If prompt life-saving first aid and medical treatment is required, decontamination procedures should be omitted. Whenever possible, response personnel should accompany contaminated victims to the medical facility to advise on matters involving decontamination.

B. Physical Injury

Physical injuries can range from a sprained ankle to a compound fracture, from a minor cut to massive bleeding. Depending on the seriousness of the injury, treatment may be given at the site by trained response personnel. For more serious injuries, additional assistance may be required at the site or the victim may have to be treated at a medical facility.

Life-saving care should be instituted immediately without considering decontamination. The outside garments can be removed (depending on the weather) if they do not cause delays, interfere with treatment, or aggravate the problem. Respirators and backpack assemblies must always be removed. Fully encapsulating suits or chemical-resistant clothing can be cut away. If the outer contaminated garments cannot be safely removed, the individual should be wrapped in plastic, rubber, or blankets to help prevent contaminating the inside of ambulances and medical personnel. Outside garments are then removed at the medical facility. No attempt should be made to wash or rinse the victim at the site. One exception would be if it is known that the individual has been contaminated with an extremely toxic or corrosive material which could also cause severe injury or loss of life. For minor medical problems or injuries, the normal decontamination procedure should be followed.

C. Heat Stress

Heat-related illnesses range from heat fatigue to heat stroke, the most serious. Heat stroke requires prompt treatment to prevent irreversible damage or death. Protective clothing may have to be cut off. Less serious forms of heat stress require prompt attention or they may lead to a heat stroke. Unless the victim is obviously contaminated, decontamination should be omitted or minimized and treatment begun immediately.

D. Chemical Exposure

Exposure to chemicals can be divided into two categories:

- Injuries from direct contact, such as acid burns or inhalation of toxic chemicals.

- Potential injury due to gross contamination on clothing or equipment.

For inhaled contaminants treatment can only be by qualified physicians. If the contaminant is on the skin or in the eyes, immediate measures must be taken to counteract the substance's effect. First aid treatment usually is flooding the affected area with water; however, for a few chemicals, water may cause more severe problems.

When protective clothing is grossly contaminated, contaminants may be transferred to treatment personnel or the wearer and cause injuries. Unless severe medical problems have occurred simultaneously with splashes, the protective clothing should be washed off as rapidly as possible and carefully removed.

V. PROTECTION FOR DECONTAMINATION WORKERS

The Level of Protection worn by decontamination workers is determined by:

- Expected or visible contamination on workers.
- Type of contaminant and associated respiratory and skin hazards.
- Total vapor/gas concentrations in the CRC.
- Particulates and specific inorganic or organic vapors in the CRC.
- Results of swipe tests.

A. Level C Use

Level C includes a full-face, canister-type air-purifying respirator, hard hat with face shield (if splash is a problem), chemical-resistant boots and gloves, and protective clothing. The body covering recommended is chemical-resistant overalls with an apron, or chemical-resistant overalls and jacket.

A face shield is recommended to protect against splashes because respirators alone may not provide this protection. The respirator should have a canister approved for filtering any specific known contaminants such as ammonia, organic vapors, acid gases, and particulates.

B. Level B Use

In situations where site workers may be contaminated with unknowns, highly volatile liquids, or highly toxic materials, decontamination workers should wear Level B protection.
Level B protection includes SCBA, hard hat with face shield, chemical-resistant gloves, and protective covering. The clothing suggested is chemical-resistant overalls, jacket, and a rubber apron. The rubber apron protects the SCBA harness assembly and regulator from becoming contaminated.

VI. DECONTAMINATION OF EQUIPMENT

Insofar as possible, measures should be taken to prevent contamination of sampling and monitoring equipment. Sampling devices become contaminated, but monitoring instruments, unless they are splashed, usually do not. Once contaminated, instruments are difficult to clean without damaging them. Any delicate instrument which cannot be easily decontaminated should be protected while it is being used. It should be placed in a clear plastic bag, and the bag taped and secured around the instrument. Openings are made in the bag for sample intake.

A. Decontamination Procedures

1. Sampling devices

Sampling devices require special cleaning. The EPA Regional Laboratories can provide information on proper decontamination methods.

2. Tools

Wooden tools are difficult to decontaminate because they absorb chemicals. They should be kept on site and handled only by protected workers. At the end of the response, wooden tools should be discarded. For decontaminating other tools, Regional Laboratories should be consulted.

3. Respirators

Certain parts of contaminated respirators, such as the harness assembly and leather or cloth components, are difficult to decontaminate. If grossly contaminated, they may have to be discarded. Rubber components can be soaked in soap and water and scrubbed with a brush. Regulators must be maintained according to manufacturer's recommendations. Persons responsible for decontaminating respirators should be thoroughly trained in respirator maintenance.

4. Heavy Equipment

Bulldozers, trucks, back-hoes, bulking chambers, and other heavy equipment are difficult to decontaminate. The method generally used is to wash them with water under high pressure and/or to scrub accessible parts with detergent/water solution under pressure, if possible. In some cases, shovels, scoops, and lifts have been sand blasted or steam cleaned. Particular care must be given to those components in direct contact with contaminants such as tires and scoops. Swipe tests should be utilized to measure effectiveness.

B. Sanitizing of Personnel Protective Equipment

Respirators, reusable protective clothing, and other personal articles not only must be decontaminated before being reused, but also sanitized. The inside of masks and clothing becomes soiled due to exhalation, body oils, and perspiration. The manufacturer's instructions should be used to sanitize the respirator mask. If practical, protective clothing should be machine washed after a thorough decontamination; otherwise it must be cleaned by hand.

C. Persistent Contamination

In some instances, clothing and equipment will become contaminanted with substances that cannot be removed by normal decontamination procedures. A solvent may be used to remove such contamination from equipment if it does not destroy or degrade the protective material. If persistent contamination is expected, disposable garments should be used. Testing for persistent contamination of protective clothing and appropriate decontamination must be done by qualified laboratory personnel.

D. Disposal of Contaminated Materials

All materials and equipment used for decontamination must be disposed of properly. Clothing, tools, buckets, brushes, and all other equipment that is contaminated must be secured in drums or other containers and labeled. Clothing not completely decontaminated on-site should be secured in plastic bags before being removed from the site.

Contaminated wash and rinse solutions should be contained by using step-in-containers (for example, child's wading pool) to hold spent solutions. Another containment method is to dig a trench about 4 inches deep and line it with plastic. In both cases the spent solutions are transferred to drums, which are labeled and disposed of with other substances on site.

VII. ANNEXES

Annex 1, 2, and 3 describe basic decontamination procedures for a worker wearing Level A, B, or C protection. The basic decontamination lines (Situation 1), consisting of approximately 19 stations, are almost identical except for changes necessitated by different protective clothing or respirators. For each annex, three specific situations are described in which the basic (or full decontamination) procedure is changed to take into account differences in the extent of contamination, the accompanying changes in equipment worn, and other factors. The situations illustrate decontamination setups based on known or assumed conditions at an incident. Many other variations are possible.

Annex 4 describes a minimum layout for Level A personnel decontamination. The number of individual stations have been reduced. Although the decontamination equipment and amount of space required is less than needed in the procedures previously described, there is also a much higher probability of cross-contamination.

ANNEX 1

LEVEL A DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level A protection (with taped joints between gloves, boots, and suit) consisting of:

- Fully encapsulating suit.
- Self-contained breathing apparatus.
- Hard hat (optional).
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment:
various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water.

Equipment:
container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash fully encapsulating suit and boots. Scrub suit and boots with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes

Station 8: Suit/Safety Boot Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long handle, soft-bristle scrub brushes

Station 9: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boots covers donned, and joints taped. Worker then returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: Fully Encapsulating Suit and Hard Hat Removal

With assistance of helper, remove fully encapsulating suit (and hard hat). Hang suits on rack or lay out on drop cloths.

Equipment: rack
drop cloths
bench or stool

Station 12: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment: table

Station 13: Inner Glove Wash

Wash with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: basin or bucket
decon solution
or
detergent/water
small table

Station 14: Inner Glove Rinse

Rinse with water. Repeat as many times as necessary.

Equipment: water basin
basin or bucket
small table

Station 15: Facepiece Removal

Remove facepiece. Deposit in container with plastic liner. Avoid touching face with fingers.

Equipment: container (30-50 gallons)
plastic liners

Station 16: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 17: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Inner clothing should be removed as soon as possible since there is a possibility that small amounts of contaminants might have been transferred in removing fully encapsulating suit.

Equipment: container (30-50 gallons)
plastic liners

Station 18: Field Wash

Shower if highly toxic, skin-corrosive or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap
small table
basin or bucket
field showers
towels

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

SIT	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X			X	X	X	X	
4	X						X	X	X										

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely toxic substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new air tank and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new air tank and will return to Exclusion Zone.

ANNEX 2

LEVEL B DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level B protection (with taped joints between gloves, boot, and suit) consisting of:

- One-piece, hooded, chemical-resistant splash suit.
- Self-contained breathing apparatus.
- Hard hat.
- Chemical-resistant, steel toe and shank boots.
- Boot covers
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water.

Equipment: container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment:
container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment:
container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment:
container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment:
container (20-30 gallons
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash chemical-resistant splash suit, SCBA, gloves, and safety boots. Scrub with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Wrap SCBA regulator (if belt-mounted type) with plastic to keep out water. Wash backpack assembly with sponges or cloths.

Equipment:
container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes
small buckets
sponges or cloths

Station 8: Suit/SCBA/Boot/Glove Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
small buckets
2-3 long-handle, soft-bristle scrub brushes
sponges or cloths

Station 9: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boots covers donned, and joints taped. Worker returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment: table

Station 12: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 13: Inner Glove Wash

Wash inner gloves with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: decon solution
or
detergent/water
basin or bucket
small table

Station 14: Inner Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment: water
basin or bucket
small table

Station 15: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners

Station 16: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 17: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off-site since there is a possibility small amounts of contaminants might have been transferred in removing fully encapsulating suit.

Equipment: container (30-50 gallons)
plastic liners

Station 18: Field Wash

Shower if highly toxic, skin-corrosive, or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap
small tables
basins or buckets
field showers

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

SIT	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X			X	X	X	X	X
4	X						X	X	X										

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely toxic substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new air tank and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new air tank and will return to Exclusion Zone.

ANNEX 3

LEVEL C DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level C protection (with taped joints between gloves, boots, and suit) consisting of:

- One-piece, hooded, chemical-resistant splash suit.
- Canister equipped, full-face mask.
- Hard hat.
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water.

Equipment: container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash splash suit and safety boots. Scrub with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes

Station 8: Suit/Safety Boot Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 9: Canister or Mask Change

If worker leaves Exclusion Zone to change canister (or mask), this is the last step in the decontamination procedure. Worker's canister is exchanged, new outer gloves and boots covers donned, and joints taped. Worker returns to duty.

Equipment: canister (or mask)
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
bench or stool
liner

Station 12: Inner Glove Wash

Wash inner gloves with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: decon solution
or
detergent/water
basin or bucket

Station 13: Inner Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment: water
basin or bucket
small table

Station 14: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit facepiece in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners

Station 15: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 16: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off-site since there is a possibility small amounts of contaminants might have been transferred in removing splash suite.

Equipment: container (30-50 gallons)
plastic liners

Station 17: Field Wash

Shower if highly toxic, skin-corrosive or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap
tables
wash basins/buckets
field showers

Station 18: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

SIT	STATION NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X									
3	X						X	X		X	X			X	X	X	X	
4	X						X	X	X									

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely skin corrosive substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new canister or mask and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new canister or mask and will return to Exclusion Zone.

ANNEX 4

LEVEL A DECONTAMINATION, MINIMUM LAYOUT

A. EQUIPMENT WORN

The decontamination procedure outlined is for workers wearing Level A protection (with taped joints between gloves, boots, and suit) consisting of:

- Fully encapsulating suit with integral boots and gloves.
- Self-contained breathing apparatus.
- Hard hat (optional).
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop clothes

Station 2: Outer Garment, Boots, and Gloves Wash and Rinse

Scrub outer boots, outer gloves, and fully-encapsulating suit with decon solution or detergent water. Rinse off using copious amounts of water.

Equipment: containers (30-50 gallons)
decon solution
or
detergent water

rinse water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Outer Boot and Glove Removal

Remove outer boots and gloves. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 4: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boot covers donned, joints taped, and worker returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 5: Boot, Gloves, and Outer Garment Removal

Boots, fully-encapsulating suit, and inner gloves removed and deposited in separate containers lined with plastic.

Equipment: containers (30-50 gallons)
plastic liners
bench or stool

Station 6: SCBA Removal

SCBA backpack and facepiece is removed. Hands and face are thoroughly washed. SCBA deposited on plastic sheets.

Equipment: plastic sheets
basin or bucket
soap and towels
bench

Station 7: Field Wash

Thoroughly wash hands and face. Shower as soon as possible.

Equipment: water
soap
tables
wash basin/bucket

PART 8

AIR SURVEILLANCE

I. INTRODUCTION

Accidents involving hazardous materials or remedial actions at abandoned waste sites can release a variety of substances into the air. Chemical fires, transportation accidents, open or leaking containers, wind-blown dust, and site cleanup activities produce emissions which can rapidly affect the health and safety of response workers and the public. Hazardous atmospheres can involve:

- Flammable or explosive vapors, gases, and aerosols (explosive atmosphere).
- Displacement of breathable air (oxygen-deficient atmosphere).
- Radioactive materials (radioactive environment).
- Toxic vapors, gases, and aerosols (toxic atmosphere).

The presence of one or more of these hazards determines subsequent actions to protect people or the environment, operations to mitigate the incident, and safety considerations for response workers.

Airborne hazards can be predicted if the substance involved, its chemical and physical properties, and weather conditions are known. But air surveillance is necessary to confirm predictions, to identify or measure contaminants, or to detect unknown air pollutants.

This part provides guidance primarily on longer-term air sampling for toxic substances. Information is given in Part 4, Initial Site Entry Survey and Reconnaissance, regarding initial determination of airborne hazards.

II. OBJECTIVE OF AIR SURVEILLANCE

Air surveillance consists of air monitoring (using direct-reading instruments capable of providing real-time indications of air contaminants) and air sampling (collecting air on an appropriate media or in a suitable sampling container followed by analysis.)

The objective of air surveillance during response is to determine the type of chemical compound (and associated hazard) and quantity of airborne contaminants on-site and off-site and changes in air contaminants that occur over the lifetime of the incident.

The data obtained are used to help establish criteria for worker safety, document potential exposures, determine protective measures for the public, evaluate the environmental impact of the incident, and determine mitigation activities. To accomplish this requires establishing an effective air surveillance program, tailored to meet the conditions generated by each incident.

III. TYPES OF INCIDENTS

As part of initial hazard evaluation, direct-reading instruments (DRIs), visible indicators (signs, labels, placards, type of container, etc.), and other information (manifests, consists, inventories, Agency records, etc.) are used to evaluate the presence or potential for air contaminant release. Limited air sampling may also be conducted if time is available. Based on an assessment of this preliminary information, a more comprehensive air surveillance strategy is developed and implemented.

Two general types of incidents are encountered:

- Environmental emergencies, including chemical fires, spills, or other releases of hazardous materials which occur over a relatively short period of time. Since contaminants may be released rapidly, there may be no time for air surveillance. In incidents where the released material can be quickly identified (and sufficient time is available), direct-reading, hand-held monitoring instruments can be used to provide information on some types of hazards. Air sampling generally is limited unless the release continues long enough for appropriate equipment to be brought in.

- Longer-term cleanup, including planned removals and remedial actions at abandoned waste sites as well as restoration after emergency problems have been controlled. During this period, especially at waste sites, workers and the public may be exposed to a wide variety of airborne materials over a much longer period of time. Since cleanup activities require more time (and planning) to accomplish, appropriate equipment for air monitoring and sampling can be secured, and an air surveillance program established.

IV. GENERAL SURVEILLANCE METHODS

During site operations, data are needed about air contaminants and any changes that may occur. Surveillance for vapors, gases, and particulates is done using DRIs and air sampling systems. DRIs can be used to detect many organics and a few inorganics and provide approximate total concentrations. If specific organics (and inorganics) have been identified, then DRIs, calibrated to those materials, can be used for more accurate on-site assessment. In many instances however, only air sampling (and laboratory analysis) can be used for detection and quantification.

The most accurate method for evaluating any air contaminant is to collect samples and analyze them at a reliable laboratory. Although accurate, this method has two disadvantages: cost and the time required to obtain results. Analyzing large numbers of samples in laboratories is very expensive, especially if results are wanted quickly. On-site laboratories tend to reduce the turn-around time, but unless they can analyze other types of samples, they also are costly. In emergencies, time is often not available for laboratory analysis of samples either on-site or off-site.

To obtain air monitoring data rapidly at the site, instruments utilizing flame ionization detectors (FIDs) photoionization detectors (PIDs) and other similar instruments can be used. These may be used as survey instruments (total concentration mode) or operated as gas chromatographs (gas chromatograph mode). As gas chromatographs, these instruments can provide real-time, qualitative/quantative data when calibrated with standards of known air contaminants. Combined with selective laboratory analysis of samples, they provide a tool for evaluating airborne organic hazards on a realtime basis, at a lower cost than analyzing all samples in a laboratory. An example of an air surveillance program used by the U.S. Environmental Protection Agency's Environmental Response Team is contained in Annex 1.

V. AIR SAMPLING

For more complete information about air contaminants, measurements obtained with DRIs must be supplemented by collecting and analyzing air samples. To assess air contaminants more thoroughly, air sampling devices equipped with appropriate collection media are placed at various locations throughout the area. These samples provide air quality information for the period of time they operate, and can indicate contaminant types and concentrations over the lifetime of site operations. As data are obtained (from the analysis of samples, DRIs, knowledge about materials involved, site operations, and potential for airborne toxic hazards), adjustments are made in the type of samples, number of samples collected, frequency of sampling, and analysis required. In addition to air samplers, area sampling stations may also include DRIs equipped with recorders and operated as continuous air monitors. Area sampling stations are located in various places including:

- Upwind - Because many hazardous incidents occur near industries or highways that generate air pollutants, samples must be taken upwind of the site to establish background levels of air contaminants.

- Support zone - Samples must be taken near the command post or other support facilities to ensure that they are in fact located in a clean area, and that the area remains clean throughout operations at the site.

- Contamination reduction zone - Air samples should be collected along the decontamination line to ensure that decontamination workers are properly protected and that on-site workers are not removing their protective gear in a contaminated area.

- Exclusion zone - The exclusion zone presents the greatest risk of exposure to chemicals and requires the most air sampling. The location of sampling stations should be based upon hot-spots detected by DRIs, types of substance present, and potential for airborne contaminants. The data from these stations, in conjunction with intermittent walk-around surveys with DRIs, are used to verify the selection of proper levels of worker protection and exclusion zone boundaries, as well as to provide a continual record of air contaminants.

- Downwind - One or more sampling stations are located downwind from the site to indicate if any air contaminants are leaving the site. If there are indications of airborne hazards in populated areas, additional samplers should be placed downwind.

VI. MEDIA FOR COLLECTING AIR SAMPLES

Hazardous material incidents, especially abandoned waste sites, involve thousands of potentially dangerous substances - gases, vapors, and aerosols that could become airborne. A variety of media - liquids and solids - are used to collect these substances. Sampling systems typically include a calibrated air sampling pump which draws air into selected collection media. Some of the most common types of samples, and the collection media used for them are:

- Organic vapors - Activated carbon is an excellent adsorbent for most organic vapors. However, other solid adsorbents (such as Tenax, silica gel, and Florisil) are routinely used to sample specific organic compounds or classes of compounds that do not adsorb or desorb well on activated carbon. To avoid stocking a large number of sorbents for all substances anticipated, a smaller number chosen for collecting the widest range of materials or for substances known to be present generally are used. The vapors are collected using an industrial hygiene personal sampling pump with either one sampling port or a manifold capable of simultaneously collecting samples on several sorbent tubes, for example, a manifold with four sorbent tubes (or as individual pumps with varying flow rates). The tubes might contain:

    -- Activated carbon to collect vapors of materials with a boiling point above 0 degrees centigrade. These materials include most odorous organic substances, such as solvent vapors.

    -- A porous polymer such as Tenax or Chromosorb to collect substances (such as high-molecular-weight hydrocarbons, organophosphorous compounds, and the vapors of certain pesticides) that adsorb poorly onto activated carbon. Some of these porous polymers also adsorb organic materials at low ambient temperatures more efficiently than carbon.

-- A polar sorbent such as silica gel to collect organic vapors (aromatic amines, for example) that exhibit a relatively high dipole moment.

-- Another specialty adsorbent selected for the specific site. For example, a Florisil tube could be used if polychlorinated biphenyls are expected.

- Inorganic gases - The inorganic gases present at an incident would primarily be polar compounds such as the haloacid gases. They can be adsorbed onto silica gel tubes and analyzed by ion chromatography. Impingers filled with selected liquid reagents can also be used.

- Aerosols - Aerosols (solid or liquid particulates) that may be encountered at an incident include contaminated and noncontaminated soil particles, heavy-metal particulates, pesticide dusts, and droplets of organic or inorganic liquids. An effective method for sampling these materials is to collect them on a particulate filter such as a glass fiber or membrane type. A backup impinger filled with a selected absorbing solution may also be necessary.

Colorimetric detector tubes can also be used with a sampling pump when monitoring for some specific compounds. Passive organic vapor monitors can be substituted for the active system described if passive monitors are available for the types of materials suspected to be present at a given site.

The National Institute for Occupational Safety and Health's (NIOSH) Manual of Analytical Methods, Volumes 1-7, contains acceptable methods for collecting and analyzing air samples for a variety of chemical substances. Consult it for specific procedures.

VII. COLLECTION AND ANALYSIS

Samples are analyzed to determine types and quantities of substances present. The following provides additional guidance on sample collection and analysis.

- Aerosols

Samples for aerosols should be taken at a relatively high flow rate (generally about 2 liters/minute) using a standard industrial hygiene pump and filter assembly. To collect total particulates, a membrane filter having a 0.8 micrometer pore size is common. The sample can be weighed to determine total particulates, then analyzed destructively or non-destructively for metals. If the metals analysis is done nondestructively or if the filter is sectioned, additional analyses (for example, organics, inorganics, and optical particle sizing) can be performed.

- Sorbent Samples

The sorbent material chosen, the amount used, and sample volume will vary according to the types and concentrations of substances anticipated at a particular site. Polar sorbent material such as silica gel will collect polar substances which are not adsorbed well onto activated carbon and some of the porous polymers. The silica gel sample can be split and analyzed for the haloacid gases and aromatic amines.

Activated carbon and porous polymers will collect a wide range of compounds. Exhaustive analysis to identify and quantify all the collected species is prohibitively expensive at any laboratory and technically difficult for a field laboratory. Therefore, samples should be analyzed for principal hazardous constituents (PHCs). The selection of PHCs should be based upon the types of materials anticipated at a given site, from generator's records, and from information collected during the initial site survey. To aid in the selection of PHCs, a sample could be collected on activated carbon or porous polymer during the initial site survey and exhaustively analyzed off-site to identify the major peaks within selected categories. This one thorough analysis, along with what is already known about a particular site, could provide enough information to select PHCs. Standards of PHCs could then be prepared and used to calibrate instruments used for field analysis of samples. Subsequent, routine off-site analysis could be limited to scanning for only PHCs, saving time and money. Special adsorbents and sampling conditions can be used for specific PHCs if desired, while continued multimedia sampling will provide a base for analysis of additional PHCs that may be identified during the course of cleanup operations.

- Passive Dosimeters

A less traditional method of sampling is the use of passive dosimeters. The few passive dosimeters now available are only for gases and vapors. Passive dosimeters are used primarily to monitor personal exposure, but they can be used to monitor areas. Passive monitors are divided into two groups:

-- Diffusion samplers, in which molecules move across a concentration gradient, usually achieved within a stagnant layer of air, between the contaminated atmosphere and the indicator material.

-- Permeation devices, which rely on the natural permeation of a contaminant through a membrane. A suitable membrane is selected that is easily permeated by the contaminant of interest and impermeable to all others. Permeation dosimeters are therefore useful in picking out a single contaminant from a mixture of possible interfering contaminants.

Some passive dosimeters may be read directly, as are DRIs and colorimetric length-of-stain tubes. Others require laboratory analysis similiar to that done on solid sorbents.

VIII. PERSONNEL MONITORING

In addition to area atmospheric sampling, personnel monitoring - both active and passive - can be used to sample for air contaminants. Representative workers are equipped with personal samplers to indicate contaminants at specific locations or for specific work being done. Placed on workers, generally within 1 foot of the mouth and nose, the monitors indicate the potential for the worker to inhale the contaminant.

IX. CALIBRATION

As a rule, the total air sampling system should be calibrated rather than the pump alone. Proper calibration is essential for proper operation and for accurate interpretation of resultant data. As a minimum, the system should be calibrated prior to and after use. The overall frequency of calibration will depend upon the general handling and use of a given sampling system. Pump mechanisms should be recalibrated after repair, when newly purchased, and following suspected abuse. Calibration methods can be found in the NIOSH Manual of Analytical Methods (Volumes 1-7).

X. METEOROLGICAL CONSIDERATIONS

Meteorological information is an integral part of an air surveillance program. Data concerning wind speed and direction, temperature, barometric pressure, and humidity, singularly or in combination, are needed for:

- Selecting air sampling locations.
- Calculating air dispersion.
- Calibrating instruments.
- Determining population at risk or environmental exposure from airborne contaminants.

Knowledge of wind speed and direction is necessary to effectively place air samplers. In source-oriented ambient air sampling particularly, samplers need to be located downwind (at different distances) of the source and others placed to collect background samples. Shifts in wind direction must be known and samplers relocated or corrections made for the shifts. In addition, atmodpheric simulation models for predicting contaminant dispersion and concentration need windspeed and direction as inputs for predictive calculations. Information may be needed concerning the frequency and intensity with which that winds blow from certain directions (windrose data), consequently, the wind direction must be continually monitored.

Air sampling systems need to be calibrated before use and corrections in the calibration curves made for temperature and pressure. After sampling, sampled air volumes are also corrected for temperature and pressure variations. This requires knowing air temperature and pressure.

Air sampling is sometimes designed to assess population exposure (and frequently potential worker exposure). Air samplers are generally located in population centers irrespective of wind direction. Even in these instances, however, meteorological data is needed for air dispersion modeling. Models are then used to predict or verify population-oriented sampling results.

Proper data is collected by having meteorological stations on site or obtaining it from one or more of several government or private organizations which routinely collect such data. The choice of how information is obtained depends on the availability of reliable data at the location desired, resources needed to obtain meteorological equipment, accuracy of information needed, and use of information.

ANNEX 5

GUIDE TO ENVIRONMENTAL RESPONSE TEAM'S AIR SURVEILLANCE PROGRAM

I. APPROACH

A variety of long-term air surveillance programs can be designed to detect a wide range of airborne compounds. To implement any program a number of factors must be considered, including type of equipment, costs, personnel required, accuracy of analysis, time required to obtain results (turn-around-time), and availability of analytical laboratories.

One approach to air surveillance, developed and used by the USEPA Environmental Response Team (ERT), is described here. This program achieves a reasonable balance between cost, accuracy, and time in obtaining data using a combination of direct reading instruments (DRIs) and air sampling systems to:

- Rapidly survey for airborne organic vapors and gases.
- Identify and measure organic vapors and gases.
- Identify and measure particulates and inorganic vapors and gases.

The approach is based on:

- Using flame ionization detectors (FIDs) and/or photoionization detectors (PIDs) for initial detection of total organic gases and vapors and for periodic site surveys (for total organics). Equipped with strip chart recorders, the detectors are used as area monitors to record total organic concentration and changes in concentration over a period of time. Calibrated to specific organic contaminants, they are used to detect and measure those substances.
- Collecting area air samples using personal pumps and organic gas/vapor collection tubes. Samples are analyzed using the gas chromatograph (GC) capabilities of field instruments. Selected samples are also analyzed in laboratories accredited by the American Industrial Hygiene Association (AIHA).
- Using PIDs and/or FIDs (as a survey instrument or GC) to provide real-time data and to screen the number of samples needed for laboratory analysis.

- Sampling for particulates, inorganic acids, aromatic amines, halogenated pesticides, etc., when they are known to be involved or when there are indications that these substances may be a problem.

II. EQUIPMENT

At present, the following equipment is used for organic gas/vapor monitoring however, other equivalent equipment can be substituted:

- HNU Systems Photoionizer (PID)
- Foxboro OVA (FID)
- MDA Accuhaler 808 Sampling Pump
- Gillian Model Number HFS-UT113 Sampling Pump
- Tenax adsorption tubes (metal)
- Carbon-packed adsorption tubes (metal)
- Carbon-packed adsorption tubes (glass)
  - 150 milligram and 600 milligram sizes

III. PROCEDURE

This procedure is generally applicable to most responses. However, since each incident is unique, modifications may be needed.

Organic Gases and Vapors. The sequence for monitoring organic gases and vapors consists of several steps.

- Determine total background concentrations.

- Determine total concentration on-site.

- Collect on-site area samples.

- Identify specific contaminants.

Background concentrations. Background readings of total organic gases and vapors, using DRIs (FID/PID), are made upwind of the site in areas not expected to contain air contaminants. If industries, highways, or other potential sources contribute to concentrations on-site, these contributions should be determined. Depending on the situation and the time available, additional monitoring should be done nearby to determine if contaminants are leaving the site.

Concentrations on-site. The on-site area is monitored (using DRIs) for total gas/vapor concentrations, measured at both ground and breathing zone levels. The initial walk-throughs are to determine general ambient concentrations and to locate higher-than ambient concentrations (hot-spots).

Transient contributors on-site, for example, exhausts from engines, should be avoided. Concentrations are recorded and plotted on a site map. Additional DRI monitoring is then done to thoroughly define any hot-spots located during the survey.

Area samples. Sampling stations are located throughout the site. The number and locations depend on evaluating many factors, including hot-spots (by DRI), active work areas, potentials for high concentrations, and wind direction. As a minimum, stations should be located in a clean off-site area (control or background station), exclusion zone, and downwind of the site. As data are accumulated, location, number of stations, and frequency of sampling can be adjusted.

Routinely, two 4-hour samples are collected, in the morning and afternoon respectively, using personal sampling pumps equipped with Tenax and/or carbon-packed, metal adsorption tubes. Total gas/vapor concentration (using DRI) should also be determined at the start and finish of each sampling run. The readings obtained may show an approximate relationship (depending on organics present) which will be helpful later in placing samplers.

Samples are desorbed with a thermal desorber and analyzed on the OVA-GC for total organic concentration and number of peaks. Chromatograms of samples taken at the same location but at different times or from different stations can be compared. Differences in heights of "total" peak, number of independent peaks, and relative peak heights, if judiciously interpreted, are useful for making preliminary judgments concerning air contaminant problems. Page A5-6 shows a suggested format for calculating total gas/vapor concentration.

If relatively high concentrations are detected by the initial DRI surveys samplers equipped with carbon-packed collection tubes (glass) are run next to Tenax/carbon-packed, metal equipped samplers. The latter samples are analyzed in the field. The carbon-packed collection tubes are analyzed by an AIHA accredited laboratory.

Area surveys using DRI are continued routinely two-four times daily. These surveys are to monitor for general ambient levels, as well as levels at sampling stations, hot-spots, and other areas of site activities. As information is accumulated on airborne organics, the frequency of surveys can be adjusted.

Specific contaminants. Personal monitoring pumps with carbon-packed collection tubes (glass) are run on the first afternoon, concurrent with samplers equipped with Tenax/carbon-packed, metal collection tubes. Generally, when total gas/vapor readings are low and only a few peaks seen (from the field GC analysis of morning samples), 100-150 mg carbon-packed tubes (glass) are used and operated at a flow rate of 100 cubic centimeters/minute until approximately 30 liters of air have been collected. Depending on suspected contaminants and their concentrations, higher flow rates and/or volumes may be needed. When total gas/vapor readings are high and there are many peaks (from the morning samples), then larger glass carbon collection tubes (600 mg) are operated at a flow rate from 0.5 to 1 liters/minute to collect 90 to 150 liters of air.

The results from laboratory analysis of glass carbon tubes are used for a number of different purposes, including:

- To identify and measure organic gases and vapors collected during the sampling period.
- To compare laboratory chromatograms and field chromatograms. If only a few peaks (but the same number) are seen on each chromatogram (and identified on the laboratory chromatogram) from samples collected at the same location, it may be reasonable to assume, until standards are run on the field GC, that the two chromatograms are identifying the same materials.
- To identify major contaminants on laboratory chromatograms and determine what standards to prepare for the field GC. Field GC's can then be used to identify and measure air contaminants against laboratory prepared standards.
- To use the field GC as a screening device for determining when samples should be collected for laboratory analysis, or when samples previously collected should be analyzed. Changes in the number of peaks on the field chromatograms from samples collected at the same location indicate changes in the air, suggesting the need for collecting additional samples for laboratory analysis.

If desorption equipment is not available for on-site sample analysis, glass collection tubes should be collected daily. Only samples collected every third to fifth day are sent to AIHA accredited laboratories for analysis; the remaining samples are stored in a cool place (preferably refrigerated). Selected stored samples are analyzed if third to fifth day samples indicate changes in air contaminant patterns. If daily on-site surveys detect low contaminant(s) levels, then 100-150 mg glass carbon columns are used. If the survey reveals relatively high levels of contaminants, then 600 mg glass carbon tubes are used.

The National Institute for Occupational Safety and Health P&CAM Analytical Method No. 127 (see Annex 6) should be followed as closely as possible. Flow rates and collection tubes described in this guide are primarily for organic solvents. If other than organic solvents are suspected, then the NIOSH Manual of Analytical Methods (Volume 1-7) should be consulted for the appropriate collection media and flow rates. Table 1 lists the organic solvents identified by the NIOSH P&CAM No. 127, many of which are found at hazardous waste sites. These are identified for possible gas chromatography/mass spectrometry analysis.

Particulates and Inorganic Gases and Vapors. Sampling for particulates is not done routinely. If these types of air contaminants are known or suspected to exist, a sampling program is instituted for them. Incidents where these contaminants might be present are: fires involving pesticides or chemicals, incidents involving heavy metals, arsenic, or cyanide compounds, or mitigation operations that create dust (from contaminated soil and excavation of contaminated soil).

Sampling media and analytical methods for these air contaminants should follow guidance given in the NIOSH Manual of Analytical Methods.

SAMPLE CALCULATION

1. Volume sampled by MDA Accuhaler 808 Personal Sampling Pump:

   Volume sampled (cc) = (final stroke count - initial stroke count) X (cc's/stroke*) X (multiplier factor for orifice used**)

   *Specified on pump itself.
   **Specified in pump operations manual and Table 2. (for MDA Accuhaler)

   Calculation:

   At beginning of sampling period, Accuhaler stroke counter reads 16292.9. At end of sampling period, it reads 16632.9. What is the volume of air sampled?

   Volume sampled (cc) = 16632.9 (final stroke count) - 16292.9 (initial stroke count) X 5.7 (cc/pump stroke) X 1.1 (multiplier for orifice)

   Volume sampled = 2131.8 cc or 2.1 liters.

2. Reporting Format (for OVA GC Thermal Desorber)

   a. Total GC Mode: Total concentration determined = 22 ppm as CH_4 (methane)

   b. $$\text{Time weighted average (ppm)} = \frac{\text{volume desorbed (liters)} \times \text{concentration (ppm)}}{\text{volume collected (liters)}}$$

   $$= \frac{0.300\ \text{(liter)} \times 22\ \text{(ppm)}}{2.1\ \text{(liters)}} = 3.14\ \text{ppm as } CH_4 \text{ (methane)}$$

   c. Peaks: GC mode
   4 peaks observed

   d. Survey Concentration (total organics by DRI)

   Start of sampling period __________ ppm, time __________

   End of sampling period __________ ppm, time __________

ATTACH CHROMATOGRAM

TABLE 1

Organic Solvents Identified by P&CAM Analytic Method No. 127

Organic Solvent	Molecular Weight
Acetone	58.1
Benzene	78.1
Carbon tetrachloride	154.0
Chloroform	119.0
Dichloromethane	84.9
p-Dioxane	88.1
Ethylene dichloride	99.0
Methyl ethyl ketone	72.1
Styrene	104.0
Tetrachloroethylene	166.0
Toluene	92.1
1,1,2-Trichloroethane	133.0
1,1,1-Trichloroethane (methyl chloroform)	133.0
Trichloroethylene	131.0
Xylene	106.0

Reference: Manual of Analytical Methods
U.S. Department of Health Education & Welfare,
Public Health Service, Center for Disease Control
National Institute of Occupational Safety & Health,
DHEW (NIOSH) Publication No. 77-157-A

TABLE 2

Multiplier Factor for MDA Accuhaler 808

Personal Sampling Pumps

	Orifice Color	Normal Flow Rate - cc/min	Volume/Stroke Multiplier
Calibration at 20 cc/min	Yellow	100	1.1
	Orange	50	1.06
	Red	20	1.00
	Brown	10	0.99
	Purple	5	0.97
	Blue	2	.
	Green	1	.
	Black	0.5	.

Reference: Instruction Manual, Accuhaler, Personnel Sampling Pump Models 808 and 818
MDA Scientific, Inc., Elmdale Avenue,
Glenview, IL 60025

ANNEX 6

ORGANIC SOLVENTS IN AIR

Physical and Chemical Analysis Branch

Analytical Method

Analyte:	Organic Solvents (See Table 1)	**Method No.:**	P&CAM 127
Matrix:	Air	**Range:**	For the specific compound, refer to Table 1
Procedure:	Adsorption on charcoal desorption with carbon disulfide, GC		
Date Issued:	9/15/72	**Precision:**	10.5% RSD
Date Revised:	2/15/77	**Classification:**	See Table 1

1. Principle of the Method

1.1 A known volume of air is drawn through a charcoal tube to trap the organic vapors present.

1.2 The charcoal in the tube is transferred to a small, graduated test tube and desorbed with carbon disulfide.

1.3 An aliquot of the desorbed sample is injected into a gas chromatograph.

1.4 The area of the resulting peak is determined and compared with areas obtained from the injection of standards.

2. Range and Sensitivity

The lower limit in mg/sample for the specific compound at 16 × 1 attenuation on a gas chromatograph fitted with a 10:1 splitter is shown in Table 1. This value can be lowered by reducing the attenuation or by eliminating the 10:1 splitter.

3. Interferences

3.1 When the amount of water in the air is so great that condensation actually occurs in the tube, organic vapors will not be trapped. Preliminary experiments indicate that high humidity severely decreases the breakthrough volume.

3.2 When two or more solvents are known or suspected to be present in the air, such information (including their suspected identities), should be transmitted with the sample, since with differences in polarity, one may displace another from the charcoal.

3.3 It must be emphasized that any compound which has the same retention time as the specific compound under study at the operating conditions described in this method is an interference. Hence, retention time data on a single column, or even on a number of columns, cannot be considered as proof of chemical identity. For this reason it is important that a sample of the bulk solvent(s) be submitted at the same time so that identity(ies) can be established by other means.

3.4 If the possibility of interference exists, separation conditions (column packing, temperatures, etc.) must be changed to circumvent the problem.

4. Precision and Accuracy

4.1 The mean relative standard deviation of the analytical method is 8% (11.4).

4.2 The mean relative standard deviation of the analytical method plus field sampling using an approved personal sampling pump is 10% (11.4). Part of the error associated with the method is related to uncertainties in the sample volume collected. If a more powerful vacuum pump with associated gas-volume integrating equipment is used, sampling precision can be improved.

4.3 The accuracy of the overall sampling and analytical method is 10% (NIOSH–unpublished data) when the personal sampling pump is calibrated with a charcoal tube in the line.

5. Advantages and Disadvantages of the Method

5.1 The sampling device is small, portable, and involves no liquids. Interferences are minimal, and most of those which do occur can be eliminated by altering chromatographic conditions. The tubes are analyzed by means of a quick, instrumental method. The method can also be used for the simultaneous analysis of two or more solvents suspected to be present in the same sample by simply changing gas chromatographic conditions from isothermal to a temperature-programmed mode of operation.

5.2 One disadvantage of the method is that the amount of sample which can be taken is limited by the number of milligrams that the tube will hold before overloading. When the sample value obtained for the backup section of the charcoal tube exceeds 25% of that found on the front section, the possibility of sample loss exists. During sample storage, the more volatile compounds will migrate throughout the tube until equilibrium is reached (33% of the sample on the backup section).

5.3 Furthermore, the precision of the method is limited by the reproducibility of the pressure drop across the tubes. This drop will affect the flow rate and cause the volume to be imprecise, because the pump is usually calibrated for one tube only.

6. Apparatus

6.1 An approved and calibrated personal sampling pump for personal samples. For an area sample, any vacuum pump whose flow can be determined accurately at 1 liter per minute or less.

6.2 Charcoal tubes: glass tube with both ends flame sealed, 7 cm long with a 6-mm O.D. and a 4-mm I.D., containing 2 sections of 20/40 mesh activated charcoal separated by a 2-mm portion of urethane foam. The activated charcoal is prepared from coconut shells and is fired at 600°C prior to packing. The absorbing section contains 100 mg of charcoal, the backup section 50 mg. A 3-mm portion of urethane foam is placed between the outlet end of the tube and the backup section. A plug of silylated glass wool is placed in front of the absorbing section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of 1 lpm.

6.3 Gas chromatograph equipped with a flame ionization detector.

6.4 Column (20 ft × ⅛ in) with 10% FFAP stationary phase on 80/100 mesh, acid-washed DMCS Chromosorb W solid support. Other columns capable of performing the required separations may be used.

6.5 A mechanical or electronic integrator or a recorder and some method for determining peak area.

6.6 Microcentrifuge tubes, 2.5 ml, graduated.

6.7 Hamilton syringes: 10 μl, and convenient sizes for making standards.

6.8 Pipets: 0.5-ml delivery pipets or 1.0-ml type graduated in 0.1-ml increments.

6.9 Volumetric flasks: 10 ml or convenient sizes for making standard solutions.

7. Reagents

7.1 Spectroquality carbon disulfide (Matheson Coleman and Bell).

7.2 Sample of the specific compound under study, preferably chromatoquality grade.

7.3 Bureau of Mines Grade A helium.

7.4 Prepurified hydrogen.

7.5 Filtered compressed air.

8. Procedure

8.1 **Cleaning of Equipment:** All glassware used for the laboratory analysis should be detergent washed and thoroughly rinsed with tap water and distilled water.

8.2 **Calibration of Personal Pumps.** Each personal pump must be calibrated with a representative charcoal tube in the line. This will minimize errors associated with uncertainties in the sample volume collected.

8.3 Collection and Shipping of Samples

8.3.1 Immediately before sampling, the ends of the tube should be broken to provide an opening at least one-half the internal diameter of the tube (2 mm).

8.3.2 The small section of charcoal is used as a back-up and should be positioned nearest the sampling pump.

8.3.3 The charcoal tube should be vertical during sampling to reduce channeling through the charcoal.

8.3.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

8.3.5 The flow, time, and/or volume must be measured as accurately as possible. The sample should be taken at a flow rate of 1 lpm or less to attain the total sample volume required. The minimum and maximum sample volumes that should be collected for each solvent are shown in Table 1. The minimum volume quoted must be collected if the desired sensitivity is to be achieved.

8.3.6 The temperature and pressure of the atmosphere being sampled should be measured and recorded.

8.3.7 The charcoal tubes should be capped with the supplied plastic caps immediately after sampling. Under no circumstances should rubber caps be used.

8.3.8 One tube should be handled in the same manner as the sample tube (break, seal, and transport), except that no air is sampled through this tube. This tube should be labeled as a blank.

8.3.9 Capped tubes should be packed tightly before they are shipped to minimize tube breakage during shipping.

8.3.10 Samples of the suspected solvent(s) should be submitted to the laboratory for qualitative characterization. These liquid bulk samples should not be transported in the same container as the samples or blank tube. If possible, a bulk air sample (at least 50 l air drawn through tube) should be shipped for qualitative identification purposes.

8.4 Analysis of Samples

8.4.1 Preparation of Samples. In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool is removed and discarded. The charcoal in the first (larger) section is transferred to a small stoppered test tube. The separating section of foam is removed and discarded; the second section is transferred to another test tube. These two sections are analyzed separately.

8.4.2 Desorption of Samples. Prior to analysis, one-half ml of carbon disulfide is pipetted into each test tube. (All work with carbon disulfide should be performed in a hood because of its high toxicity.) Tests indicate that desorption is complete in 30 minutes if the sample is stirred occasionally during this period.

8.4.3 GC Conditions. The typical operating conditions for the gas chromatograph are:

1. 85 cc/min. (70 psig) helium carrier gas flow.
2. 65 cc/min. (24 psig) hydrogen gas flow to detector.
3. 500 cc/min. (50 psig) air flow to detector.
4. 200°C injector temperature.
5. 200°C manifold temperature (detector).
6. Isothermal oven or column temperature — refer to Table 1 for specific compounds.

8.4.4 Injection. The first step in the analysis is the injection of the sample into the gas chromatograph. To eliminate difficulties arising from blowback or distillation within the syringe needle, one should employ the solvent flush injection technique. The 10 µl syringe is first flushed with solvent several times to wet the barrel and plunger. Three microliters of solvent are drawn into the syringe to increase the accuracy and reproducibility of the injected sample volume. The needle is removed from the solvent, and the plunger is pulled back about 0.2 µl to separate the solvent flush from the sample with a pocket of air to be used as a marker. The needle is then immersed in the sample, and a 5-µl aliquot is withdrawn, taking into consideration the volume of the needle, since the sample in the needle will be completely injected. After the needle is removed from the sample and prior to injection, the plunger is pulled back a short distance to minimize evaporation of the sample from the tip of the needle. Duplicate injections of each sample and standard should be made. No more than a 3% difference in area is to be expected.

8.4.5 Measurement of area. The area of the sample peak is measured by an electronic integrator or some other suitable form of area measurement, and preliminary results are read from a standard curve prepared as discussed below.

8.5 Determination of Desorption Efficiency

8.5.1 Importance of determination. The desorption efficiency of a particular compound can vary from one laboratory to another and also from one batch of charcoal to another. Thus, it is necessary to determine at least once the percentage of the specific compound that is removed in the desorption process for a given compound, provided the same batch of charcoal is used. NIOSH has found that the desorption efficiencies for the compounds in Table 1 are between 81% and 100% and vary with each batch of charcoal.

8.5.2 Procedure for determining desorption efficiency. Activated charcoal equivalent to the amount in the first section of the sampling tube (100 mg) is measured into a 5-cm, 4-mm I.D. glass tube, flame-sealed at one end (similar to commercially available culture tubes). This charcoal must be from the same batch as that used in obtaining the samples and can be obtained from unused charcoal tubes. The open end is capped with Parafilm. A known amount of the compound is injected directly into the activated charcoal with a microliter syringe, and the tube is capped with more Parafilm. The amount injected is usually equivalent to that present in a 10-liter sample at a concentration equal to the federal standard.

At least five tubes are prepared in this manner and allowed to stand for at least overnight to assure complete absorption of the specific compound onto the charcoal. These five tubes are referred to as the samples. A parallel blank tube should be treated in the same manner except that no sample is added to it. The sample and blank tubes are desorbed and analyzed in exactly the same manner as the sampling tube described in Section 8.4.

Two or three standards are prepared by injecting the same volume of compound into 0.5 ml of CS_2 with the same syringe used in the preparation of the sample. These are analyzed with the samples.

The desorption efficiency equals the difference between the average peak area of the samples and the peak area of the blank divided by the average peak area of the standards, or

$$\text{desorption efficiency} = \frac{\text{Area sample} - \text{Area blank}}{\text{Area standard}}$$

9. Calibration and Standards

It is convenient to express concentration of standards in terms of mg/0.5 ml CS_2 because samples are desorbed in this amount of CS_2. To minimize error due to the volatility of carbon disulfide, one can inject 20 times the weight into 10 ml of CS_2. For example, to prepare a 0.3 mg/0.5 ml standard, one would inject 6.0 mg into exactly 10 ml of CS_2 in a glass-stoppered flask. The density of the specific compound is used to convert 6.0 mg into microliters for easy measurement with a microliter syringe. A series of standards, varying in concentration over the range of interest, is prepared and analyzed under the same GC conditions and during the same time period as the unknown samples. Curves are established by plotting concentration in mg/0.5 ml versus peak area.

NOTE: Since no internal standard is used in the method, standard solutions must be analyzed at the same time that the sample analysis is done. This will minimize the effect of known day-to-day variations and variations during the same day of the FID response.

10. Calculations

10.1 The weight, in mg, corresponding to each peak area is read from the standard curve for the particular compound. No volume corrections are needed, because the standard curve is based on mg/0.5 ml CS_2 and the volume of sample injected is identical to the volume of the standards injected.

10.2 Corrections for the blank must be made for each sample.

$$\text{Correct mg} = \text{mg}_s - \text{mg}_b$$

where:

mg_s = mg found in front section of sample tube
mg_b = mg found in front section of blank tube

A similar procedure is followed for the backup sections.

10.3 The corrected amounts present in the front and backup sections of the same sample tube are added to determine the total measured amount in the sample.

10.4 This total weight is divided by the determined desorption efficiency to obtain the corrected mg per sample.

10.5 The concentration of the analyte in the air sampled can be expressed in mg per m³.

$$\mathrm{mg/m^3} = \frac{\text{Corrected mg (Section 10.4)} \times 1000\ (\text{liters/m}^3)}{\text{Air volume sampled (liters)}}$$

10.6 Another method of expressing concentration is ppm (corrected to standard conditions of 25°C and 760 mm Hg).

$$\mathrm{ppm} = \mathrm{mg/m^3} \times \frac{24.45}{MW} \times \frac{760}{P} \times \frac{(T + 273)}{298}$$

where:

P = pressure (mm Hg) of air sampled
T = temperature (°C) of air sampled
24.45 = molar volume (liter/mole) at 25°C and 760 mm Hg
MW = molecular weight
760 = standard pressure (mm Hg)
298 = standard temperature (°K)

11. References

11.1 White, L. D., D. G. Taylor, P. A. Mauer, and R. E. Kupel, "A Convenient Optimized Method for the Analysis of Selected Solvent Vapors in the Industrial Atmosphere", Am Ind Hyg Assoc J 31:225, 1970.

11.2 Young, D. M. and A. D. Crowell, Physical Adsorption of Gases, pp. 137-146, Butterworths, London, 1962.

11.3 Federal Register, 37:202:22139-22142, October 18, 1972.

11.4 NIOSH Contract HSM-99-72-98, Scott Research Laboratories, Inc., "Collaborative Testing of Activated Charcoal Sampling Tubes for Seven Organic Solvents", pp. 4-22, 4-27, 1973.

TABLE 1

Parameters Associated With P&CAB Analytical Method No. 127

Organic Solvent	Method Classification	Detection limit (mg/sample)	Sample Volume (liters) Minimum[a]	Sample Volume (liters) Maximum[b]	GC Column Temp.(°C)	Molecular Weight
Acetone	D	–	0.5	7.7	60	58.1
Benzene	A	0.01	0.5	55	90	78.1
Carbon tetrachloride	A	0.20	10	60	60	154.0
Chloroform	A	0.10	0.5	13	80	119
Dichloromethane	D	0.05	0.5	3.8	85	84.9
p-Dioxane	A	0.05	1	18	100	88.1
Ethylene dichloride	D	0.05	1	12	90	99.0
Methyl ethyl ketone	B	0.01	0.5	13	80	72.1
Styrene	D	0.10	1.5	34	150	104
Tetrachloroethylene	B	0.06	1	25	130	166
1,1,2-trichloroethane	B	0.05	10	97	150	133
1,1,1-trichloroethane (methyl chloroform)	B	0.05	0.5	13	150	133
Trichloroethylene	A	0.05	1	17	90	131
Toluene	B	0.01	0.5	22	120	92.1
Xylene	A	0.02	0.5	31	100	106

(a) Minimum volume, in liters, required to measure 0.1 times the OSHA standard

(b) These are breakthrough volumes calculated with data derived from a potential plot (11.2) for activated coconut charcoal. Concentrations of vapor in air at 5 times the OSHA standard (11.3) or 500 ppm, whichever is lower, 25°C, and 760 torr were assumed. These values will be as much as 50% lower for atmospheres of high humidity. The effects of multiple contaminants have not been investigated, but it is suspected that less volatile compounds may displace more volatile compounds (See 3.1 and 3.2)

PART 9

SITE SAFETY PLAN

I. INTRODUCTION

The purpose of the site safety plan is to establish requirements for protecting the health and safety of responders during all activities conducted at an incident. It contains safety information, instructions, and procedures.

A site safety plan must be prepared and reviewed by qualified personnel for each hazardous substance response. Before operations at an incident commence, safety requirements must be written, conspicuously posted or distributed to all response personnel, and discussed with them. The safety plan must be periodically reviewed to keep it current and technically correct.

In non-emergency situations, for example, long-term remedial action at abandoned hazardous waste sites, safety plans are developed simultaneously with the general work plan. Workers can become familiar with the plan before site activities begin. Emergency response generally requires verbal safety instructions and reliance on existing standard operating procedures until, when time permits, a plan can be written.

The plan must contain safety requirements for routine (but hazardous) response activities and also for unexpected site emergencies. The major distinction between routine and emergency site safety planning is the ability to predict, monitor, and evaluate routine activities. A site emergency is unpredictable and may occur anytime.

II. GENERAL REQUIREMENTS

The site safety plan must:

- Describe the known hazards and evaluate the risks associated with the incident and with each activity conducted.
- List key personnel and alternates responsible for site safety, response operations, and for protection of public.
- Describe Levels of Protection to be worn by personnel.
- Delineate work areas.
- Establish procedures to control site access.
- Describe decontamination procedures for personnel and equipment.
- Establish site emergency procedures.

- Address emergency medical care for injuries and toxicological problems.

- Describe requirements for an environmental surveillance program.

- Specify any routine and special training required for responders.

- Establish procedures for protecting workers from weather-related problems.

III. SITE SAFETY PLAN SCOPE AND DETAIL

The plan's scope, detail, and length is based on:

- Information available about the incident.

- Time available to prepare a site-specific plan.

- Reason for responding.

Three general categories of response exist - emergencies, characterizations and remedial actions. Although considerations for personnel safety are generic and independent of the response category, in scope, detail, and length safety requirements and plans vary considerably. These variations are generally due to the reason for responding (or category of response) , information available, and the severity of the incident with its concomitant dangers to the responder.

A. Emergencies

1. Situation:

Emergencies generally require prompt action to prevent or reduce undesirable affects. Immediate hazards of fire, explosion, and release of toxic vapors or gases are of prime concern. Emergencies vary greatly in respect to types and quantities of material, numbers of responders, type of work required, population affected, and other factors. Emergencies last from a few hours to a few days.

- Information available: Varies from none to much. Usually information about the chemicals involved and their associated hazards is quickly obtained in transportation-related incidents, or incidents involving fixed facilities. Determining the substances involved in some incidents, such as mysterious spills, requires considerable time and effort.

- Time available: Little time, generally requires prompt action to bring the incident under control.

- Reason for response: To implement prompt and immediate actions to control dangerous or potentially dangerous situations.

2. Effects on Plan

In emergencies, time is not available to write lengthy and detailed safety plans. Decisions for responder safety are based on a continual evaluation of changing conditions. Responding organizations must rely on their existing written standard operating safety procedures or a generic plan, and verbal safety instructions adapted to meet site-specific conditions. Since heavy reliance is placed on verbal safety instructions an effective system to keep all responders informed must be established. Whenever possible, these incident-specific instructions should be written.

B. Incident Characterization

1. Situation:

In non-emergency responses,for example, preliminary inspections at abandoned wastes sites or more comprehensive waste site investigations the objective is to determine and characterize the chemicals and hazards involved, the extent of contamination, and risks to people and the environment. In general, initial inspections, detailed investigations, and extent of contamination surveys are limited in the activities that are required and number of people involved. Initial or preliminary inspections generally require 1-2 days. Complete investigations may last over a longer time period.

- Information available: Much background information. Generally limited on-site data for initial inspection. On-site information more fully developed through additional site visits and investigations.
- Time available: In most cases adequate time is available to develop written site-specific safety plan.
- Reason for response: To gather data to verify or refute existing information, to gather information to determine scope of subsequent investigations, or to collect data for planning remedial action.

2. Effects on Plan:

Sufficient time is available to write safety plans. In scope and detail, plans tend to be brief containing safety requirements for specific on-site work relevant to collecting data. As information is developed through additional investigations, the safety plan is modified and, if necessary, more detailed and specific requirements added.

C. Remedial Actions

1. Situation:

Remedial actions are cleanups which last over a long period of time. They commence after more immediate problems at an emergency have been controlled, or they involve the mitigation of hazards and restoration of abandoned hazardous waste sites. Numerous activities are required involving many people, a logistics and support base, extensive equipment, and more involved work activities. Remedial actions may require months to years to completely accomplish.

- Information available: Much known about on-site hazards.
- Time available: Ample time for work planning.
- Reason for response: Systematic and complete control, cleanup, and restoration.

2. Effects on Plan:

Since ample time is available before work commences, site safety plan tends to be comprehensive and detailed. From prior investigations much detail may be known about the materials or hazards at the site and extent of contamination.

IV. SITE SAFETY PLAN DEVELOPMENT

To develop the plan as much background information as possible should be obtained, time permitting, about the incident. This would include, but not be limited to:

- Incident location and name.
- Site description.
- Chemicals and quantities involved.
- Hazards associated with each chemical.
- Behavior and dispersion of material involved.
- Types of containers, storage, or transportation methods.
- Physical hazards.
- Prevailing weather condition and forecast.
- Surrounding populations and land use.
- Ecologically sensitive areas.

- Facility records.
- Preliminary assessment reports.
- Off-site surveys.
- Topographic and hydrologic information.

The information initially available or obtained through subsequent characterization provides a basis for developing a site-specific safety plan. Information is needed about the chemicals and hazards involved, movement of material on and off the site, and potential contact with responders or the public. This type of information is then used along with the reason for responding (and work plan) to develop the safety plan. The plan is tailored to the conditions imposed by the incident and to its environmental setting. As additional information becomes available the safety plan is modified to protect against the hazards discerned and to provide for site emergencies that may occur.

V. ROUTINE OPERATIONS

Routine operations are those activities required in responding to an emergency or a remedial action at a hazardous waste site. These activities may involve a high degree of risk, but are standard operations that all incident responses may require.

Safety practices for routine operations closely parallel accepted industrial hygiene and industrial safety procedures. Whenever a hazardous incident progresses to the point where operations become more routine, the associated site safety plan becomes a more refined document. As a minimum, the following must be included as part of the site safety plan for routine operations.

- Describe the Known Hazards and Risks

  This must include all known or suspected physical, biological, radiological, or chemical hazards. It is important that all health related data be kept up-to-date. As air, water, soil, or hazardous substance monitoring and sampling data becomes available, it must be evaluated, significant risk or exposure to workers noted, potential impact on public assessed, and changes made in the plan. These evaluations need to be repeated frequently since much of the plan is based on this information.

- List Key Personnel and Alternates

  The plan must identify key personnel (and alternates) responsible for site safety. It should also identify key personnel assigned to various site operations. Telephone numbers, addresses, and organizations of these people must be listed in the plan and posted in a conspicuous place.

- Designate Levels of Protection to be Worn

  The Levels of Protection to be worn at locations on-site or by work functions must be designated. This includes the specific types of respirators and clothing to be worn for each level. No one shall be permitted in areas requiring personnel protective equipment unless they have been trained in its use and are wearing it.

- Delineate Work Areas

  Work areas (exclusion zone, contamination reduction zone, and support zone) need to be designated on the site map and the map posted. The size of zones, zone boundaries, and access control points into each zone must be marked and made known to all site workers.

- List Control Procedures

  Control procedures must be implemented to prevent unauthorized access. Site security procedures - fences, signs, security patrols, and check-in procedures - must be established. Procedures must also be established to control authorized personnel into work zones where personnel protection is required.

- Establish Decontamination Procedures

  Decontamination procedures for personnel and equipment must be established. Arrangements must also be made for the proper disposal of contaminated material, solutions, and equipment.

- Address Requirements for an Environmental Surveillance Program

  A program to monitor site hazards must be implemented. This would include air monitoring and sampling, and other kinds of media sampling at or around the site that would indicate chemicals present, their hazards, possible migration, and associated safety requirements.

- Specify Any Routine and Special Training Required

  Personnel must be trained not only in general safety procedures and use of safety equipment, but in any specialized work they may be expected to do.

- Establish Procedures for Weather-Related Problems

  Weather conditions can affect site work. Temperature extremes, high winds, storms, etc. impact on personnel safety. Work practices must be established to protect workers from the effects of weather and shelters provided, when necessary. Temperature extremes, especially heat and its effect on people wearing protective clothing, must be considered and procedures established to monitor for and minimize heat stress.

VI. ON-SITE EMERGENCIES

The plan must address site emergencies - occurrences that require immediate actions to prevent additional problems or harm to responders, the public, property, or the environment. In general, all responses present a degree of risk to the workers. During routine operations risk is minimized by establishing good work practices and using personnel protective equipment. Unpredictable events such as fire, chemical exposure, or physical injury may occur and must be anticipated. The plan must contain contingencies for managing them.

- Establish Site Emergency Procedures
  - List the names and emergency function of on-site personnel responsible for emergency actions along with the special training they have.
  - Post the location of nearest telephone (if none at site).
  - Provide alternative means for emergency communications.
  - Provide a list of emergency services organizations that may be needed. Names, telephone numbers, and locations must be posted. Arrangements for using emergency organizations should be made beforehand. Organizations that might be needed are:
    - Fire
    - Police
    - Health
    - Explosive experts
    - Local hazardous material response units
    - Civil defense
    - Rescue
  - Address and define procedures for the rapid evacuation of workers. Clear, audible warnings signals should be established, well-marked emergency exits located throughout the site, and internal and external communications plans developed. An example of codes that could be used for emergency operations based on direct-reading instruments is contained in Annex 7.
  - A complete list of emergency equipment should be attached to the safety plan. This list should include emergency equipment available on-site, as well as all available medical, rescue, transport, fire-fighting, and mitigative equipment.

- Address emergency medical care.
  - Determine location of nearest medical or emergency care facility. Determine their capability to handle chemical exposure cases.
  - Arrange for treating, admitting, and transporting of injured or exposed workers.
  - Post the medical or emergency care facilities location, travel time, directions, and telephone number.
  - Determine local physician's office location, travel directions, availability, and post telephone number if other medical care is not available.
  - Determine nearest ambulance service and post telephone number.
  - List responding organization's physicians, safety officers, or toxicologists name and telephone number. Also include nearest poison control center, if applicable.
  - Maintain accurate records on any exposure or potential exposure of site workers during an emergency (or routine operations). The minimum amount of information needed (along with any medical test results) for personnel exposure records is contained in Annex 8.
- Advise workers of their duties during an emergency. In particular, it is imperative that the site safety officers, standby rescue personnel, decontamination workers, and emergency medical technicians practice emergency procedures.
- Incorporate into the plan, procedures for the decontamination of injured workers and for their transport to medical care facilities. Contamination of transport vehicles, medical care facilities, or of medical personnel may occur and should be addressed in the plan. Whenever feasible these procedures should be discussed with appropriate medical personnel in advance of operations.
- Establish procedures in cooperation with local and state officials for evacuating residents who live near the site.

VII. IMPLEMENTATION OF THE SITE SAFETY PLAN

The site safety plan, (standard operating safety procedure or a generic safety plan for emergency response) must be written to avoid misinterpretation, ambiguity, and mistakes that verbal orders cause. The plan must be reviewed and approved by qualified personnel. Once the safety plan is implemented, its needs to be periodically examined and modified, if necessary, to reflect any changes in site work and conditions.

All agencies and organizations which have an active role at the incident must be familiar with the plan. If possible the plan should be written in coordination with the organizations involved. Lead personnel from these organizations should sign the plan to signify they agree with it and will follow its provisions.

All personnel involved at the site must be familiar with the safety plan, or the parts that pertain to their specific activities. Frequent safety meeting should be held to keep all informed about site hazards, changes in operating plans, modifications of safety requirements, and for exchanges of information. It is the responsibility of personnel involved at the site as workers or visitors to comply with the requirements in the plan.

Frequent audits by the incident manager or the safety designee should be made to determine compliance with the plan's requirements. Any deviations should be brought to the attention of the incident manager. Modifications in the plan should be reviewed and approved by appropriate personnel.

VIII. SAMPLE SAFETY PLANS

Annex 9 and 10 are two examples of Site Safety Plans. Since no one sample plan or plan format can adequately address all safety requirements for the variety of incidents that occur, they should be used as a guide to help develop an incident-specific plan. They can also be used, with necessary adaptation, as generic plans for emergency response.

In some incidents, the sample plans contained in Annex 9 and 10 might be satisfactory to use by themself. By filling in the blanks an effective safety plan is available. In many incidents they should only be considered as a check list (which does not exhaustively cover every condition) which must be addressed. Users of these sample plans and any other type examples must realize their application to any one incident may not be acceptable. Therefore they must be used with discretion and tempered by professional judgement and experience. They are not meant to be all inclusive but examples of considerations, requirements, and format which should be adapted for incident-specific conditions.

ANNEX 7

Emergency Operation Codes
Real-Time Monitor
(suggested minimum action plan)

____________(Site Name)____________

CODE DESIGNATIONS

1. GREEN

   A. Normal operations

2. YELLOW A

   A. Cessation of specific work activity on-site because of:

      (1) Continuous organic readings on direct-reading instrument of __*__ ppm above background (measured 20-30 ft. from point of suspected release), and

      (2) Current or projected meterological conditions indicate a probable impact on work activity.

   B. If background readings above __*__ ppm are obtained during cessation of activity, redesign activity to lower releases and/or delay that on-site activit until off-site air monitoring indicates accepted off-site concentration.

   C. Site personnel will immediately notify EPA/State of site condition.

3. YELLOW B

   A. Termination of all work on-site because of:

      (1) Continuous organic readings on direct-reading instrument above __*__ ppm: (measured approximately 1,000 ft. from work area or site property limits), and

      (2) Current or projected meteorologic conditions indicate a potential impact on inhabited areas.

   B. Site personnel will immediately notify EPA/State of site conditions.

   C. EPA/State will modify off-site air monitoring to meet the needs of contingency plan.

4. RED

A. Termination of all work on-site because of:

(1) Continuous organic readings on direct-reading instruments above __*__ ppm (measured downwind at the nearest occupied area off-site, and

(2) Current or projected meteorologic conditions indicate a potential impact on inhabited areas.

B. Site personnel will immediately notify EPA/State of site conditions.

C. Local officials making evacuation/public health decisions will be advised by EPA/State to:

(1) Release a public health advisory to potentially affected areas since on-site control methods will not reduce the source of contamination; and/or

(2) Implement a temporary relocation plan because on-site activities indicate a potential for continuous above background/acceptable readings at the nearest inhabited area(s).

*Concentration should be determined by appropriate response personnel.

RESPONSE SAFETY CHECK-OFF SHEET

(minimum required data)

______________________ Employee

I. BEFORE RESPONSE

1. Incident: Site ______________________ City __________ State __________
   a. Response Dates ____

2. Type of Response: Spill _____ Fire _____ Site _____ Train _____ Other _____

3. Incident Safety Plan: Region ________ ERT _________ Not Developed _____

4. Suspected chemical(s) involved: (a) _______________ (b) _______________
   (c) ______________________________ (d) _______________________

5. Protective Level(s) involved: A ________ B ________ C ________ D ________
   (a) If Level C - 1. Identify Canister ______________________________
   2. Describe air monitoring source(s) ______________
   (b) If Level D JUSTIFY (in comments section at bottom of page).

6. SCBA-Identify Buddy: Name/Organization ______________________________

7. Last Response: (a) Level Used: A ______ B _______ C ______ D ________
   (b) Medical Attention/Exam Performed: Yes ______ No _____

II. AFTER RESPONSE

1. Protective Level Used: A ________ B ________ C ________ D ________
   a. Level C - identify cannister: ____________ b. Level D (comment below)
   c. Level B or C skin protection: Tyvek/Saran ____ Acid/Rain ____ Other _____

2. List possible chemical exposure: Same as above: _____ (a) _______________
   (b) ______________ (c) ______________ (d) ______________

3. Equipment Decontamination:

	(a) clothing	(b) respirator	(c) monitoring
Disposed:	____________	____________	____________
Cleaned:	____________	____________	____________
No Action:	____________	____________	____________

4. Approximate time in exclusion area: _______ hours per day for _______ days

5. Was medical attention/exam required for this response: Yes _____ No _____

Part I: DATE PREPARED: _______________ Reviewed by _______________ Date _____

Part II: DATE PREPARED: _______________ Reviewed by _______________ Date _____

COMMENTS: ____

____

____

ANNEX 9

(Suggested format for minimum site safety plan)

SITE SAFETY PLAN

(Name of Hazardous Waste Site/Spill)

I. General Information

As a minimum, all personnel involved with emergency response, waste site cleanup, drum handling and opening, sampling, site investigations, etc., will follow the applicable Federal/State rules and regulations. In addition, all site personnel will follow, as a minimum, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Hazardous Response Support Division's, Standard Operating Safety Guides and Chapter 9 Hazardous Substance Response, from the EPA Occupation Health and Safety Manual.

In the event of conflicting plans/requirements, personnel must implement those safety practices which afford the highest personnel protection.

If site conditions change and it is necessary to modify Levels of Protection A, B, or C the safety designee on-site shall notify the On-Scene Coordinator before making recommendations to site personnel.

II. APPROVALS

(SIGNATURE) On-Scene-Coordinator (OSC) DATE	(SIGNATURE) Safety Officer DATE
(SIGNATURE) REVIEW COMMITTEE DATE	(SIGNATURE) OTHERS DATE

III. Summary of Minimum Requirements

A. The safety officer/designee shall:

1. Describe chemicals, hazards, and risk involved
2. List key personnel
    a. Response manager (OSC)/alternate ________________
    b. Safety officer(s)/alternate ____________________
    c. Other responsible site personnel/alternate _____________
3. Prescribe Levels of Protection
4. Designate work zones: Support area, contamination reduction area, exclusion area.
5. Implement procedures to control site access.

6. Define decontamination procedures.

7. Delineate entry and escape routes.

8. Identify/contact medical facility, etc.:

    a. Fire ____________________

    b. Ambulance ________________

    c. Police __________________

    d. Health __________________

    e. Etc. ____________________

9. List responsible parties and emergency contacts:

    a. Federal Government EPA/USCG/CDC/OSHA

    b. State Government Environmental/Health Agency

    c. County/City Government ____________________

10. Establish personnel air monitoring.

11. Specify routine and special training needed

12. Establish procedures for managing weather-related problems.

B. Levels of Protection

1. Level C protection should be used for those job functions listed below where there is no potential for personnel contact with either hazardous materials or gases, vapors, or particulates exceeding requirements for wearing air-purifying respirators.

    (Identify job functions in this paragraph:
    e.g. - monitoring/surveillance, supervisors,
    observers, etc.)

    (Identify specific type of respirator in this paragraph:
    e.g. - approved respirator and type of canister.)

    (Identify skin protection in this paragraph:
    e.g. - double boots, double gloves, tyvek/saran hooded, disposable coveralls, etc.)

2. Level B protection should be used for those job functions listed below which based either on potential or known site conditions and/or vapor and gas concentrations, Level C is unsatisfactory.

   Identify job functions in this paragraph:
   (e.g. - Heavy equipment operations, samplers, equipment/drum handlers, etc.)

   Identify specific respiratory protection in this paragraph:
   (e.g. - self-contained breathing apparatus (SCBA), air-line respirator)

   Identify skin protection in this paragraph:
   (e.g. - double boots, double gloves, type of chemical resistant garment, etc)

3. If Level A protection is applicable, write a paragraph in plan listing where and when it is to be worn.

4. Level D is not adequate protection for any work on-site where potential for exposure is possible.

5. Levels C and B may be modified based on monitoring and sampling data collected on-site. Safety designee should not make any modification to the Level of Protection without discussing it with the On-Scene-Coordinator.

C. Air monitoring - Refer to, Standard Operating Safety Guides, Part 8, Air Surveillance.

D. Training

Personnel will have either formal training or prior on-the-job-training for those tasks they are assigned to at the incident. All unfamiliar activities will be rehearsed beforehand.

E. Respiratory Protection Program

All contractor and government personnel involved in on-site activities shall have a written respiratory protection program. All personnel wearing air-purifying respirator on-site are required to be fit-tested. All personnel wearing respirators must have been properly trained in their use. All respirators are to be properly decontaminated at the end of each workday.

Persons having beards or facial hair must not wear a respirator if a proper mask-to-face-seal can not be demonstrated by a fit test. A log of all individuals wearing personnel protective equipment shall be maintained including time in the exclusion zone.

F. All contractor and government personnel who are exposed to hazardous levels of chemicals must be enrolled in a medical monitoring program.

G. General Safety Rules and Equipment

1. There will be no eating, drinking, or smoking in the exclusion or contamination reduction zone.
2. All personnel must pass through the contamination reduction zone to enter or exit the exclusion zone.
3. As a minimum, emergency eye washes will be on the hot side of the contamination reduction zone and/or at the work station.
4. As a minimum, an emergency deluge shower/spray cans are to be located on the clean side of the contamination reduction area.
5. At the end of the work day, all personnel working in the exclusion area shall take a hygienic shower.
6. All supplied breathing air shall be certified as grade D or better.
7. Where practical, all tools/equipment will be spark proof, explosion resistant, and/or bonded and grounded.
8. fire extinguishers will be on-site for use on equipment or small fires only.
9. Since site evacuation may be necessary if an explosion, fire, or release occurs, an individual shall be assigned to sound an alert and notify the responsible public officals if required. For example, the evacuation signal may be two long blasts every 30 seconds until all personnel are evacuated and accounted for.
10. An adequately stocked first-aid kit will be on-scene at all times during operational hours. It is suggested that an oxygen inhalator respirator be available and a qualified operator present. The location of these items and the operator shall be posted.

H. Morning Safety Meeting

A morning safety meeting will be conducted for all site personnel and they will sign a daily attendance sheet and should sign a master sheet indicating they have read the site safety plan and will comply. The safety procedures, and the day's planned operations should be discussed.

APPENDIX A - SAMPLE SAFETY PLAN

Assistance in preparing the safety plan can be obtained from the OHS

Designee ____________ located in Room _______ of Building __________

or by telephoning _________________.

REVIEW

Response Safety Committee Chairperson ______________________

APPROVALS

OSC/SFC ______________________

OHS Designee ______________________

OIC ______________________

PROJECT LEADER

Branch ______________________

Building ______________________

Room ______________________

Phone ______________________

DATE OF PLAN PREPARATION ______________________

HAZARDOUS SUBSTANCE RESPONSE

Site Name ______________________ Site No. ____________________

HAZARDOUS/SUBSTANCES (known or suspected, contaminated media or in storage container, etc.):

____

____

____

HAZARD ASSESSMENT (toxic effects, reactivity, stability, flammability, and operational hazards with sampling, decontaminating, etc.):

MONITORING PROCEDURES (If required by the Project Leader)

Monitoring the site for identity and concentration of contamination in all media:

Medical monitoring procedures for evidence of personnel exposure:

Personnel monitoring procedures:

DECONTAMINATION AND DISPOSAL

Decontamination Procedures (contaminated: personnel surfaces, materials, instruments, equipment, etc):

____

____

____

Disposal Procedures (contaminated equipment, supplies, disposable, washwater):

____

____

____

____

EMERGENCY PROCEDURES

In event of overt personnel exposure (skin contact, inhalation, ingestion):

____

____

____

____

In event of personnel injury:

____

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____

In event of potential or actual fire or explosion:

In event of potential or actual ionizing radiation exposure:

In event of environmental accident (spread of contamination outside sites):

EMERGENCY SERVICES (complete here or have separate list available on-site)

	Location	Telephone
Emergency Medical Facility		
Ambulance Service		

____

Location	Telephone

Fire Department

____

____

____

Police Department

____

____

____

Poison Control Center

____

____

____

PERSONNEL POTENTIALLY EXPOSED TO HAZARDOUS SUBSTANCES

Personnel Authorized to Enter site

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Other Personnel Assigned to Handle Hazardous Substances (decontaminate, analyze samples)

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

ALTERNATIVE WORK PRACTICES

(Describe alternative work practices not specified in this Chapter. Indicate work practices specified in the Chapter for which proposed alternative work practices will serve as substitute.)

____

____

____

____

APPROPRIATE LITERATURE CITATIONS

LEVEL OF PROTECTION

SITE MAP

(Attach a site map in advance of a response, if possible, or at an early stage of an emergency response. Map should be properly scaled and keyed to local landmarks.)

APPENDIX I

CHARACTERISTICS OF THE HNU PHOTOIONIZER

AND

ORGANIC VAPOR ANALYZER

I. INTRODUCTION

The HNU Photoionizer and the Foxboro Organic Vapor Analyzer (OVA) are used in the field to detect a variety of compounds in air. The two instruments differ in their modes of operation and in the number and types of compounds they detect (Table I-1). Both instruments can be used to detect leaks of volatile substances from drums and tanks, determine the presence of volatile compounds in soil and water, make ambient air surveys, and collect continuous air monitoring data. If personnel are thoroughly trained to operate the instruments and to interpret the data, these instruments can be valuable tools for helping to decide the levels of protection to be worn, assist in determining other safety procedures, and determine subsequent monitoring or sampling locations.

II. OVA

The OVA operates in two different modes. In the survey mode, it can determine approximate total concentration of all detectable species in air. With the gas chromatograph (GC) option, individual components can be detected and measured independently, with some detection limits as low as a few parts per million (ppm).

In the GC mode, a small sample of ambient air is injected into a chromatographic column and carried through the column by a stream of hydrogen gas. Contaminants with different chemical structures are retained on the column for different lengths of time (known as retention times) and hence are detected separately by the flame ionization detector. A strip chart recorder can be used to record the retention times, which are then compared to the retention times of a standard with known chemical constituents. The sample can either be injected into the column from the air sampling hose or injected directly with a gas-tight syringe.

In the survey mode, the OVA is internally calibrated to methane by the manufacturer. When the instrument is adjusted to manufacturer's instructions it indicates the true concentration of methane in air. In response to all other detectable compounds, however, the instrument reading may be higher or lower than the true concentration. Relative

TABLE I-1

COMPARISON OF THE OVA AND HNU

	OVA	HNU
Response	Responds to many organic gases and vapors.	Responds to many organic and some inorganic gases and vapors.
Application	In survey mode, detects total concentrations of gases and vapors. In GC mode, identifies and measures specific compounds.	In survey mode, detects total concentrations of gases and vapors. Some identification of compounds possible, if more than one probe is used.
Detector	Flame ionization detector (FID)	Photoionization detector (PID)
Limitations	Does not respond to inorganic gases and vapors. Kit available for temperature control.	Does not respond to methane. Does not detect a compound if probe has a lower energy than compound's ionization potential.
Calibration gas	Methane	Benzene
Ease of operation	Requires experience to interpret correctly, especially in GC mode.	Fairly easy to use and interpret.
Detection limits	0.1 ppm (methane)	0.1 ppm (benzene)
Response time	2-3 seconds (survey mode) for CH_4	3 seconds for 90% of total concentration of benzene.
Maintenance	Periodically clean and inspect particle filters, valve rings, and burner chamber. Check calibration and pumping system for leaks. Recharge battery after each use.	Clean UV lamp frequently. Check calibration regularly. Recharge battery after each use.
Useful range	0-1000 ppm	0-2000 ppm
Service life	8 hours; 3 hours with strip chart recorder.	10 hours; 5 hours with strip chart recorder.

response ratios for substances other than methane are available. To correctly interpret the readout, it is necessary to either make calibration charts relating the instrument readings to the true concentration or to adjust the instrument so that it reads correctly. This is done by turning the ten-turn gas-select knob, which adjusts the response of the instrument. The knob is normally set at 3.00 when calibrated to methane. Calibration to another gas is done by measuring a known concentration of a gas and adjusting the gas select knob until the instrument reading equals that concentration.

The OVA has an inherent limitation in that it can detect only organic molecules. Also, it should not be used at temperatures lower than about 40 degrees Fahrenheit because gases condense in the pump and column. It has no column temperature control, (although temperature control kits are available) and since retention times vary with ambient temperatures for a given column, determinations of contaminants are difficult. Despite these limitations, the GC mode can often provide tentative information on the identity of contaminants in air without relying on costly, time-consuming laboratory analysis.

III. HNU

The HNU portable photoionizer detects the concentration of organic gases as well as a few inorganic gases. The basis for detection is the ionization of gaseous species. Every molecule has a characteristic ionization potential (I.P.) which is the energy required to remove an electron from the molecule, yielding a positively charged ion and the free electron. The incoming gas molecules are subjected to ultraviolet (UV) radiation, which is energetic enough to ionize many gaseous compounds. Each molecule is tranformed into charged ion pairs, creating a current between two electrodes.

Three probes, each containing a different UV light source, are available for use with the HNU. Ionizing energies of the probe are 9.5, 10.2, and 11.7 electron volts (eV). All three detect many aromatic and large molecule hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe.

The HNU factory calibration gas is benzene. The span potentiometer (calibration) knob is turned to 9.8 for benzene calibration. A knob setting of zero increases the response to benzene approximately tenfold. As with the OVA, the instrument's response can be adjusted to give more accurate readings for specific gases and eliminate the necessity for calibration charts.

While the primary use of the HNU is as a quantitative instrument, it can also be used to detect certain contaminants, or at least to narrow the range of possiblities. Noting instrument response to a contaminant source with different probes can eliminate some contaminants from consideration. For instance, a compound's ionization potential may be such that the 9.5 eV probe produces no response, but the 10.2 eV and 11.7 eV probes do elicit a response. The HNU does not detect methane.

The HNU is easier to use than the OVA. Its lower detection limit is also in the low ppm range. The response time is rapid; the meter needle reaches 90% of the indicated concentration in 3 seconds for benzene. It can be zeroed in a contaminated atomosphere and does not detect methane.

IV. GENERAL CONSIDERATIONS

Both of these instruments can monitor only certain vapors and gases in air. Many nonvolatile liquids, toxic solids, particulates, and other toxic gases and vapors cannot be detected. Because the types of compounds that the HNU and OVA can potentially detect are only a fraction of the chemicals possibly present at an incident, a zero reading on either instrument does not necessarily signify the absence of air contaminants.

The instruments are non-specific, and their response to different compounds is relative to the calibration setting. Instrument readings may be higher or lower than the true concentration. This can be an especially serious problem when monitoring for total contaminant concentrations if several different compounds are being detected at once. In addition, the response of these instruments is not linear over the entire detection range. Care must therefore be taken when interpreting the data. All identifications should be reported as tentative until they can be confirmed by more precise analysis. Concentrations should be reported in terms of the calibration gas and span potentiometer or gas-select-knob setting.

Since the OVA and HNU are small, portable instruments, they cannot be expected to yield results as accurate as laboratory instruments. They were originally designed for specific industrial applications. They are relatively easy to use and interpret when detecting total concentrations of individually known contaminants in air, but interpretation becomes extremely difficult when trying to quantify the components of a mixture. Neither instrument can be used as an indicator for combustible gases or oxygen deficiency.

The OVA (Model 128) is certified by Factory Mutual to be used in Class I, Division 1, Groups A,B,C, and D environments. The HNU is certified by Factory Mutual for use in Class I, Division 2, Groups, A, B, C, and D.

APPENDIX II

RATIONALE FOR RELATING TOTAL ATMOSPHERIC VAPOR/GAS CONCENTRATIONS TO THE SELECTION OF THE LEVEL OF PROTECTION

I. INTRODUCTION

The objective of using total* atmospheric vapor/gas concentrations for determining the appropriate Level of Protection is to provide a numerical criterion for selecting Level A, B, or C. In situations where the presence of vapors or gases is not known, or if present, the individual components are unknown, personnel required to enter that environment must be protected. Until the constituents and corresponding atmospheric concentrations of vapor, gas, or particulate can be determined and respiratory and body protection related to the toxicological properties of the identified substances chosen, total vapor/gas concentration, with judicious interpretation, can be used as a guide for selecting personnel protection equipment.

Although total vapor/gas concentration measurements are useful to a qualified professional for the selection of protective equipment, caution should be exercised in interpretation. An instrument does not respond with the same sensitivity to several vapor/gas contaminants as it does to a single contaminant. Also since total vapor/gas field instruments see all contaminants in relation to a specific calibration gas, the concentration of unknown gases or vapors may be over or under-estimated.

Suspected carcinogens, particulates, highly hazardous substances, or other substances that do not elicit an instrument response may be known or believed to be present. Therefore, the protection level should not be based solely on the total vapor/gas criterion. Rather, the level should be selected case-by-case, with special emphasis on potential exposure and chemical and toxicological characteristics of the known or suspected material.

II. FACTORS FOR CONSIDERATION

In utilizing total atmospheric vapor/gas concentrations as a guide for selecting a Level of Protection, a number of other factors should also be considered:

- The uses, limitations, and operating characteristics of the monitoring instruments must be recognized and understood. Instruments such as the HNU Photoionizer, Foxboro Organic Vapor

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*See Part VII for explanation of term.

Analyzer (OVA), MIRAN Infrared Spectrophotometer, and others do not respond identically to the same concentration of a substance or respond to all substances. Therefore, experience, knowledge, and good judgement must be used to complement the data obtained with instruments.

- Other hazards may exist such as gases not detected by the HNU or OVA, (i.e. phosgene, cyanides, arsenic, chlorine), explosives, flammable materials, oxygen deficiency, liquid/solid particles, and liquid or solid chemicals.
- Vapors/gases with a very low TLV or IDLH could be present. Total readings on instruments, not calibrated to these substances, may not indicate unsafe conditions.
- The risk to personnel entering an area must be weighed against the need for entering. Although this assessment is largely a value judgment, it requires a conscientious balancing of the variables involved and the risk to personnel against the need to enter an unknown environment.
- The knowledge that suspected carcinogens or substances extremely toxic or destructive to skin are present or suspected to be present (which may not be reflected in total vapor/gas concentration) requires an evaluation of factors such as the potential for exposure, chemical characteristics of the material, limitation of instruments, and other considerations specific to the incident.
- What needs to be done on-site must be evaluated. Based upon total atmospheric vapor concentrations, Level C protection may be judged adequate; however, tasks such as moving drums, opening containers, and bulking of materials, which increase the probability of liquid splashes or generation of vapors, gases, or particulates, may require a higher level of protection.
- Before any respiratory protective apparatus is issued, a respiratory protection program must be developed and implemented according to recognized standards (ANSI Z88.2-1980).

III. LEVEL A PROTECTION (500 to 1,000 PPM ABOVE BACKGROUND)

Level A protection provides the highest degree of respiratory tract, skin, and eye protection if the inherent limitations of the personnel protective equipment are not exceeded. The range of 500 to 1,000 parts per million (ppm) total vapors/gases concentration in air was selected based on the following criteria:

- Although Level A provides protection against air concentrations greater than 1,000 ppm for most substances, an operational restriction of 1,000 ppm is established as a warning flag to:

- evaluate the need to enter environments with unknown concentrations greater than 1,000 ppm
- identify the specific constituents contributing to the total concentration and their associated toxic properties
- determine more precisely concentrations of constituents
- evaluate the calibration and/or sensitivity error associated with the instrument(s)
- evaluate instrument sensitivity to wind velocity, humidity temperature, etc.

- A limit of 500 ppm total vapors/gases in air was selected as the value to consider upgrading from Level B to Level A. This concentration was selected to fully protect the skin until the constituents can be identified and measured and substances affecting the skin excluded.

- The range of 500 to 1,000 ppm is sufficiently conservative to provide a safe margin of protection if readings are low due to instrument error, calibration, and sensitivity; if higher than anticipated concentrations occur; and if substances highly toxic to the skin are present.

With properly operating portable field equipment, ambient air concentrations approaching 500 ppm have not routinely been encountered on hazardous waste sites. High concentrations have been encountered only in closed buildings, when containers were being opened, when personnel were working in the spilled contaminants, or when organic vapors/gases were released in transportation accidents. A decision to require Level A protection should also consider the negative aspects: higher probability of accidents due to cumbersome equipment, and most importantly, the physical stress caused by heat buildup in fully encapsulating suits.

IV. LEVEL B PROTECTION (5 to 500 ABOVE BACKGROUND)

Level B protection is the minimum Level of Protection recommended for initially entering an open site where the type, concentration, and presence of airborne vapors are unknown. This Level of Protection provides a high degree of respiratory protection. Skin and eyes are also protected, although a small portion of the body (neck and sides of head) may be exposed. The use of a separate hood or hooded, chemical-resistant jacket would further reduce the potential for exposure to this area of the body. Level B impermeable protective clothing also increases the probability of heat stress.

A limit of 500 ppm total atmospheric vapor/gas concentration on portable field instruments has been selected as the upper restriction on the use of Level B. Although Level B personnel protection should be adequate for most commonly encountered substances at air concentrations higher than 500 ppm, this limit has been selected as a decision point for a careful evaluation of the risks associated with higher concentrations. These factors should be considered:

- The necessity for entering unknown concentrations higher than 500 ppm wearing Level B protection.
- The probability that substance(s) present are severe skin hazards.
- The work to be done and the increased probability of exposure.
- The need for qualitative and quantitative identification of the specific components.
- Inherent limitations of the instruments used for air monitoring.
- Instrument sensitivity to winds, humidity, temperature, and other factors.

V. LEVEL C PROTECTION (BACKGROUND TO 5 PPM ABOVE BACKGROUND)

Level C provides skin protection identical to Level B, assuming the same type of chemical protective clothing is worn, but lesser protection against inhalation hazards. A range of background to 5 ppm above ambient background concentrations of vapors/gases in the atmosphere has been established as guidance for selecting Level C protection. Concentrations in the air of unidentified vapors/gases approaching or exceeding 5 ppm would warrant upgrading respiratory protection to a self-contained breathing apparatus.

A full-face, air-purifying mask equipped with an organic vapor canister (or a combined organic vapor/particulate canister) provides protection against low concentrations of most common organic vapors/gases. There are some substances against which full-face, canister-equipped masks do not protect, or substances that have very low Threshold Limit Values or Immediately Dangerous to Life or Health concentrations. Many of the latter substances are gases or liquids in their normal state. Gases would only be found in gas cylinders, while the liquids would not ordinarily be found in standard containers or drums. Every effort should be made to identify the individual constituents (and the presence of particulates) contributing to the total vapor readings of a few parts per million. Respiratory protective equipment can then be selected accordingly. It is exceedingly difficult, however, to provide constant, real-time identification of all components in a vapor cloud with concentrations of a few parts per million at a site where ambient concentrations are constantly changing. If highly toxic substances have been ruled out, but ambient levels of a few parts per million persist, it is unreasonable to assume only self-contained breathing apparatus should be worn. The continuous use of air-purifying masks in vapor/gas concentrations of a few parts per million gives a reasonable assurance that the respiratory tract is protected, provided that the absence of highly toxic substances has been confirmed.

Full-face, air-purifying devices provide respiratory protection against most vapors at greater than 5 ppm; however, until more definitive qualitative information is available, concentration(s) greater than 5 ppm indicates that a higher level of respiratory protection should be used. Also, unanticipated transient excursions may increase the concentrations in the environment above the limits of air-purifying devices. The increased probability of exposure due to the work being done may require Level B protection, even though ambient levels are low.

VI. INSTRUMENT SENSITIVITY

Although the measurement of total vapor/gas concentrations can be a useful adjunct to professional judgment in the selection of an appropriate Level of Protection, caution should be used in the interpretation of the measuring instrument's readout. The response of an instrument to a gas or vapor cloud containing two or more substances does not provide the same sensitivity as measurements involving the individual pure constituents. Hence the instrument readout may overestimate or underestimate the concentration of an unknown composite cloud. This same type of inaccuracy could also occur in measuring a single unknown substance with the instrument calibrated to a different substance. The idiosyncrasies of each instrument must be considered in conjunction with the other parameters in selecting the protection equipment needed.

Using the total vapor/gas concentration as a criterion used to determine Levels of Protection should provide protection against concentrations greater than the instrument's readout. However, when the upper limits of Level C and B are approached, serious consideration should be given to selecting a higher Level of Protection. Cloud constituent(s) must be identified as rapidly as possible and Levels of Protection based on the toxic properties of the specific substance(s) identified.

VII. EXPLANATION OF PHRASE TOTAL ATMOSPHERIC VAPOR/GAS CONCENTRATION

The phrase total atmospheric vapor/gas concentration is commonly used to describe the readout, in ppm, on PIDs and FIDs. More correctly it should be called a dial reading or needle deflection. In atmospheres that contain a single vapor/gas or mixtures of vapors/gases that have not been identified, the instruments do not read the total vapors/gases present only the instrument's response. This response, as indicated by a deflection of the needle in the dial, does not indicate the true concentration. Accurate dial readings can only be obtained by calibrating the instrument to the substance being measured.

APPENDIX III

DERMAL TOXICITY DATA

I. SELECTION OF CHEMICALS

The approximately 350 chemicals listed in Table III-1, at the end of this appendix, are identified in the Oil and Hazardous Materials Technical Assistance System (OHMTADS) as being dermally active. Since OHMTADS contains only about 1200 chemicals, or may not indicate a listed chemical as a skin hazard, other reference sources should also be consulted.

The data in Table III-1 were compiled by a toxicologist through a special project with the U.S. Environmental Protection Agency. As with any source of information, the data should be cross-checked against other standard references.

II. USE OF TABLES

A. Categories

Table III-1 divides chemicals into two categories:

Category 1 (more serious), which includes:

- Gases having a systemic dermal toxicity rating of moderate to extremely hazardous and a skin penetration ranking of moderate to high.
- Liquids and solids having a systemic dermal toxicity rating of extremely hazardous and a skin penetration ranking of moderate to high.
- Gases having a local dermal toxicity rating of moderate to extremely hazardous.
- Liquids and solids having a local dermal toxicity rating of extremely hazardous.

Category 2 (less serious), which includes:

- Gases having a systemic dermal toxicity rating of slightly hazardous and a skin penetration ranking of slight.
- Liquids and solids having a systemic dermal toxicity rating of slightly hazardous and a skin penetration ranking of moderate to slight.

- Gases having a local dermal toxicity rating of slightly hazardous.

- Liquids and solids having a local dermal toxicity rating of moderate to slightly hazardous.

B. Physical State

The physical state of the chemicals listed is their normal state. In a fire, some listed as solids or liquids could vaporize and represent a greater hazard to the skin. The chemicals listed may also be found mixed with other substances, which could change how they affect the skin.

C. Skin Penetration

- Negligible Penetration (solid - polar)

+ Slight Penetration (solid - nonpolar)

++ Moderate Penetration (liquid/solid - nonpolar)

+++ High Penetration (gas/liquid - nonpolar)

D. Potency (Systemic)

		Lethal amount to a 70-kilogram man
+++	Extreme Hazard (LD_{50}: 1 mg/kg-50 mg/kg)	drops to 20 ml
++	Moderate Hazard (LD_{50}: 50-500 mg/kg)	1 ounce - 1 pint (1 pound)
+	Slight Hazard (LD_{50}: 500-15,000 mg/kg)	1 pint - 1 quart (2.2 pounds)

E. Potency (Local)

+++ Extreme - Tissue destruction/necrosis

++ Moderate - Irritation/inflamation of skin

+ Slight - Reddening of skin

III. RELATION OF TABLE III-1 AND LEVELS OF PROTECTION

The purpose of Table III-1 is to provide data that a qualified person can use in conjunction with other site-specific knowledge to select protective clothing. The data relate to skin toxicity only and should not be used to select respiratory protection equipment.

The known or suspected presence and/or measured concentration of Category 1 chemicals at or above the listed concentrations warrants wearing a fully encapsulating suit (Level A). The known or suspected presence and/or measured concentration of Category 2 chemicals at or above the listed concentrations suggests that a lesser level of skin protection (Level B or C) is needed.

There is no decision-logic for choosing protective clothing as there is for choosing respiratory protective equipment. The use of a fully encapsulating suit over other types of chemical-resistant clothing is generally a judgment made by a qualified individual based on an evaluation of all pertinent information available about the specific incident. Other guidance and criteria for selecting personnel protection equipment are contained in Part 5, Site Entry - Levels of Protection and in Appendix II.

IV. OTHER REFERENCES

Table III-1 does not include all substances affecting the skin. Other standard references should be consulted, in particular:

- Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment With Intended Changes for 1982, American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Building D-5, Cincinnati, OH 45211 (1982).
- NIOSH/OSHA Pocket Guide to Chemical Hazards, U.S. Government Printing Office, Washington, DC 20402 (August 1981).
- Registry of Toxic Effects of Chemical Substances, U.S. Government Printing Office, Washington, DC 20402 (1980).

Whenever possible, data in one reference should be cross-checked with other references.

TABLE III-1

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
2,2 Dichloropropionic acid	solid	+	local	++	-	2
2,4,5 - T Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - T Amines	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - T Esters	solid	+	systemic local	+ +	10 mg/m^3/8h	2
2,4,5 - TP Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4,5 - TP Acid Esters	liquid	++	systemic local	+ +	10 mg/m^3/8h	2
2,4,5 - T Salts	solid	+	systemic local	+ +	10 mg/m^3/8h	2
2,4 - D Acid	solid	+	systemic local	+ ++	10 mg/m^3/8h	2
2,4 - Dichlorophenol	solid	+	systemic local	+ ++	-	2
2,4 - D - Esters	liquid	++	systemic local	+ +	10 mg/m^3/8h	2
2 - Ethylhexyl Acrylate	liquid	++	local	+++	-	2
2 - Methyl - 5 - ethyl pyridine	liquid	++	local	+	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
2 - Napthol	solid	+	local	++	-	2
3,5 - Xylenol	solid	+	systemic local	++ +	-	2
Acetaldehyde	liquid	+	local systemic	++ +	200 ppm/8h 360 mg/m^3/8h	2
Acetic Anhydride	liquid	+	local systemic	++ +	5 ppm/8h 20 mg/m^3/8h	2
Acetone	liquid	+++	local	++	1,000 ppm/8h 2,400 mg/m^3/8h	2
Acetone Cyanohydrin	liquid	++	systemic	+++	10 ppm/8h	1
Acetoacetone	liquid	++	local	++	-	2
Acetyl Bromide	fuming liquid	+++	local	+++	5 ppm/15 min	1
Acetyl Chloride	fuming liquid	+++	local	+++	5 ppm/15 min	1
Acridine	solid	+	local sensitizer	+++	-	2
Acrolein	liquid	+	local sensitizer	+++	0.1 ppm/8h .25 mg/m^3/8h	2
Acrylonitrile	liquid	+++	systemic local	+++ ++	2 ppm/8h	1

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Adipic Acid	solid	+	local	+	-	2
Adiponitrile	liquid	+++	systemic	+++	18 mg/m^3/8h	1
Alkyldimethyl 3,4 - Dichlorobenzylammonium Chloride	liquid	+	local	+	-	2
Allyl Alcohol	liquid	++	systemic local	++ ++	2 ppm/8h 5 mg/m^3/8h	2
Allyl Chloride	liquid	++	local	++	1 ppm/8h 3 mg/m^3/8h	2
Ammonia	gas	+	local	+++	25 ppm/8h 18 mg/m^3/8h	1
Ammonium Bicarbonate	solid	+	local	++	-	2
Ammonium Bichromate	solid	+	local	++	-	2
Ammonium Bifluoride	solid	+	local	++	-	2
Ammonium Bisulfite	solid	+	local	+++	-	2
Ammonium Carbamate	solid	+	local	+	-	2
Ammonium Carbonate	solid	+	local	++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Ammonium Citrate (Dibasic)	solid	+	local	+++	-	2
Ammonium Ferrocyanide	solid	+	local	+	-	2
Ammonium Hydroxide	liquid	++	local	+++	-	1
Ammonium Phosphate (Dibasic)	solid	+	local	++	-	2
Ammonium Sulfamate	solid	+	local	++	10 mg/m^3/8h	2
Ammonium Sulfide	solid	+	local	++	-	2
Ammonium Sulfite	solid	+	local	++	-	2
Ammonium Tartrate	solid	+	local	++	-	2
Ammonium Thiocyanate	solid	++	local systemic	+++ ++	-	2
Ammonium Thiosulfate	solid	+	local	++	-	2
Aniline	liquid	++	local	++	5 ppm/8h	2
Antimony	solid	+	systemic local	++ ++	0.5 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Antimony Pentachloride	liquid	++	local	+++	-	2
Argon - 37 (radioactive)	gas	+++	systemic	+++	-	1
Arsine	gas	+++	systemic	+++	0.05 $mg/m^3/8h$	1
Arsenic	solid	++	local systemic	+++ +++	.25 $mg/m^3/8h$	1
Arsenic-74 (radioactive)	solid	++	systemic	+++	-	1
Arsenic-76 (radioactive)	solid	++	systemic	+++	-	1
Arsenic-77 (radioactive)	solid	++	systemic	+++	-	1
Arsenic Acid	solid	++	local systemic	+++ +++	0.5 $mg/m^3/8h$	1
Arsenic Disulfide	solid	++	local systemic	+++ +++	-	1
Arsenic Pentoxide	solid	++	local systemic	+++ +++	-	1
Arsenic Tribromide	solid	++	local systemic	+++ +++	0.5 $mg/m^3/8h$	1
Arsenic Trichloride	solid	++	local systemic	+++ +++	0.5 $mg/m^3/8h$	1

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Arsenic Trioxide	solid	++	local systemic	+++ +++	.25 mg/m^3/8h	1
Arsenic Trisulfide	solid	++	local systemic	+++ +++	0.5 mg/m^3/8h	1
Barium	solid	+	local	++	0.5 mg/m^3/8h	2
Benzene	liquid	++	local systemic	++ +++	75 ppm/30 min	1
Benzophenone	solid	+	local	++	-	2
Benzoyl Chloride	liquid	++	local	+++	5 mg/m^3/8h	1
Benzoyl Peroxide	solid	++	local	+++	5 mg/m^3/8h	1
Benzyl Alcohol	liquid	++	local systemic	++ +	-	2
Benzyl Benzoate	liquid	++	local	++	-	2
Benzyl Bromide	liquid	++	local	++	-	2
Benzyl Chloride	liquid	++	local	+++	1 ppm/8h	2
Beryllium Nitrate	solid	+	local	++	0.25 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Brombenzylcyanide	liquid <77 F-solid	++	local systemic	++ +++	-	1
Calcium Hypochlorite	solid	+	local	++	-	1
Calcium Oxide	solid	+	local	++	10 mg/m^3/30 min	2
Calcium Phosphide	solid	+	local	++	-	2
Camphor	solid	+	local systemic	++ ++	2 ppm/8h	2
Captan	solid	++	local systemic	++ ++	5 mg/m^3/8h	2
Carbaryl	solid	++	local systemic	+ ++	5 mg/m^3/8h	2
Carbofuran	liquid	++	local systemic	+++ +++	0.1 mg/m^3/8h	1
Carbon Disulfide	liquid	++	local systemic	++ +++	20 ppm/8h 60 mg/m^3/8h	1
Carbon Monoxide	gas	+++	systemic	+++	50 ppm/8h	1
Carbon Tetrachloride	liquid	+++	systemic local	+++ +	10 ppm/8h	1
Cetyldimethylbenzyl-ammonium Chloride	solid	+	local	+	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Chloracetophenone	solid	+	local systemic	++ ++	.05 ppm/8h	2
Chlordane	solid	+	local systemic	++ ++	.5 $mg/m^3/8h$	2
Bromine	liquid (fuming)	++	local systemic	+++ ++	.1 ppm/8h	1
Butylamine	liquid	++	local	+++	5 ppm/8h	1
Butyl Mercaptan	liquid	++	local	++	.5 ppm/8h	2
Butyric Acid	liquid	++	local	++	-	2
Calcium Arsenate	solid	+	local systemic	++ +++	1 $mg/m^3/8h$	1
Calcium Arsenite	solid	+	local systemic	++ +++	-	1
Calcium Carbide	solid	+	local	++	-	2
Calcium Cyanide	solid	++	systemic local	+++ ++	5 $mg/m^3/10$ min	1
Chlorine	gas	+++	local	+++	1 ppm/8h 3 $mg/m^3/8h$	1
Chlorine - 36 (radioactive)	gas	+++	local	+++	-	1

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Chloroacetic Acid	solid	++	local	++	-	2
Chlorobenzene	liquid	++	local systemic	++ ++	75 ppm/8h 350 mg/m^3/8h	2
Chlorobutadiene	liquid	++	local	++	25 ppm/8h	2
Chloromethane	gas	+++	local systemic	+ ++	100 ppm/8h	1
Chloropicrin	liquid	++	local	+++	0.1 ppm/8h	1
Chlorosulfonic Acid	liquid	++	local	+++	5 ppm/8h	1
Chlorthion	liquid	++	local systemic	+++ +	-	2
Chromyl Chloride	liquid	++	local systemic	+++ ++	.1 mg/m^3/8h	1
CMU	solid	+	local systemic	+ +	-	2
Copper Naphthenate	liquid	++	local systemic	++ ++	500 ppm	2
Coumaphos	solid	+	local systemic	++ +++	-	2
Cresyldiphenyl Phosphate	liquid	++	local	++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Crotonaldehyde	liquid	++	local systemic	++ ++	2 ppm/8h	2
Cumene	liquid	++	local systemic	++ +	50 ppm/8h	2
Cupric Acetate	solid	+	local systemic	+++ ++	0.1 mg/m^3/8h	2
Cupric Acetoarsenate	solid	+	local systemic	++ ++	0.1 mg/m^3/8h	2
Cupric Sulfate, Ammoniated	solid	+	local	++	2 mg/m^3/8h	2
Cyanogen	gas	+++	systemic local	+++ ++	10 ppm/8h	1
Cyanogen Bromide	solid	++	local systemic	+++ ++	0.5 ppm/8h	1
Cyanogen Chloride	gas	+++	local systemic	++ ++	10 ppm/15 min 5 mg/m^3/8h	1
Cyclohexanol	liquid	+	local systemic	++ +	50 ppm/8h	2
Cyclohexanone	liquid	+	local systemic	++ +	50 ppm/8h	2
Cyclohexylamine	liquid	++	local systemic	++ ++	10 ppm/8h	2
Decaborane	solid	+	local systemic	++ ++	.05 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Decanal	liquid	++	local	++	-	
Diacetone Alcohol	liquid	++	local systemic	++ +	50 ppm/8h	2
Diamylamine	liquid	++	local systemic	++ ++	-	2
Diborane	gas	++	local systemic	++ ++	.1 ppm/8h	1
Dicamba	solid	+	local systemic	+ ++	-	2
Dichlobinil	solid	+	local systemic	+ +	-	2
Dichlone	solid	+	local	++	-	2
Dichlorodiflouromethane	gas	++	systemic	++	1,000 ppm/8h	2
Dichloroethyl Ether	liquid	++	local systemic	++ ++	5 ppm/8h	2
Dichloromethane	liquid	++	local systemic	++ ++	200 ppm/8h	2
Dichloropropane	liquid	++	local systemic	++ +	75 ppm/8h	2
Dichloropropene	liquid	++	local systemic	++ ++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Dichloropropene Dichloropropane	liquid	++	local systemic	++ ++	-	2
Dichlorvos	liquid	++	systemic	++	.1 ppm/8h 1 mg/m^3/8h	2
Dicyclopentadiene	liquid	++	local	+++	5 ppm/8h	2
Diethanolamine	solid	+	local	++	-	2
Diethylamine	liquid	++	local	++	25 ppm/8h	2
Diethylene Glycol	liquid	+	systemic	+	-	2
Diethylenetriamine	liquid	+	local	+++	1 ppm/8h	2
Diethyl Phthalate; Ethyl Formate	liquid	++	local	+	-	2
Dimethylamine	oily liquid	++	local	+++	10 ppm/8h 18 mg/m^3/8h	2
N,N - dimethylaniline	oily liquid	+++	systemic local	++ +	5 ppm/8h 25 mg/m^3/8h	2
Dimethylsulfate	liquid	++	local	+++	1 ppm/8h	2
Dioxane (p-dioxane)	liquid	++	local systemic	++ +	50 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Diphosgene	gas	++	local	+++	-	1
Diquat		++	local systemic	++ ++	0.5 mg/m^3/8h	2
Disulfotone	liquid	++	systemic	+++	.1 mg/m^3/8h	1
Diuron		++	local systemic	++ ++	-	2
DNBP		++	systemic	+++	-	2
DNBP-NH$_4$-salt		++	systemic	+++	-	2
1-Dodecanol	solid	+	local	+	-	2
Endosulfan	solid	++	systemic	+++	0.1 mg/m^3/8h	2
Endothal			local	++		
Epichlorohydrin	liquid	++	local systemic	+ ++	5 ppm/8h 19 mg/m^3/8h	2
Ethion	liquid	++	systemic	++	-	2
Ethyl Acetate	liquid	++	local	++	400 ppm/8h 1400 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Ethyl Acrylate	liquid	++	local systemic	++ ++	25 ppm/8h 100 mg/m^3/8h	2
Ethyl Benzene	liquid	++	local systemic	++ ++	100 ppm/8h	2
Ethyl Chloride	liquid	++	local frostbite	++	1,000 ppm/8h	2
Ethylene	gas	++	local frostbite	++	-	2
Ethylene Cyanohydrin	liquid	++	systemic	+	-	2
Ethylene Dibromide	liquid	++	local systemic	++ ++	20 ppm/8h 50 ppm/5 min	2
Ethylene Dichloride	liquid	++	local systemic	++ ++	10 ppm/8h 200 ppm/5 min	2
Ethylene Glycol Diacetate	liquid	++	systemic	+	-	2
Ethylene Glycol Monoethyl Ether Acetate	liquid	++	systemic local	+ +	100 ppm/8h	2
Ethylene Glycol Monoethyl Ether	liquid	++	systemic	+	25 ppm/8h	2
Ethylene Oxide	liquid	+	local	+++	50 ppm/8h	2
Ethyl Ether	liquid	+	local	+++	400 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Ferbam	solid	+	local systemic	+ +	15 $mg/m^3/8h$	2
Ferric Hydroxide	solid	-	local	++	-	2
Ferric Nitrate	solid	-	local	++	1 $mg/m^3/8h$	2
Ferric Sulfate	solid	-	local	++	-	2
Ferrous Sulfate	solid	-	local	++	-	2
Ferrous Hydroxide	solid	-	local	++	-	2
Ferrous Sulfite	solid	-	local	++	-	2
Fish Oil	liquid	++	local allergen	+	-	2
Fluorine	gas	+++	local	+++	.1 ppm	1
Formaldehyde	liquid	++	local systemic	+++ ++	3 ppm/8h	2
Formic acid	liquid	++	local	+++	5 ppm/8h	2
Furfural	liquid	++	local	+++	5 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Gas oils	liquid	++	local	+	-	2
Glyoxal	liquid	+	local	+	-	2
Guthion	solid	++	systemic	++	-	2
Heptachlor	solid	+++	systemic local	++ +	.5 mg/m^3/8h	2
Heptane	liquid	++	local systemic	+ ++	500 ppm/8h	2
Heptanol	liquid	++	local systemic	+ ++	-	2
HETP	liquid	+++	systemic	+++	-	1
Hexaborane	liquid	++	local systemic	++ ++	-	2
Hexamethylenediamine	solid	++	local systemic	+++ ++	-	2
Hexane	liquid	++	local systemic	+ ++	500 ppm/8h	2
Hexanol	liquid	++	local	+++ ++	-	2
Hexylene Glycol	liquid	++	local systemic	++ +	25 ppm/8h 125 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Hydrazine	liquid	++	local systemic	+++ ++	1 ppm/8h	1
Hydrochloric Acid	liquid	++	local systemic	+++ +	5 ppm/8h	1
Hydrofluoric Acid	liquid	++	local systemic	+++ +	3 ppm/8h	1
^{3}H (Tritium) (Radioactive)	gas	+++	systemic	+++	-	1
Hydrogen Cyanide	gas	+++	systemic	+++	10 ppm/8h	1
Hydrogen Fluoride	gas	+++	local	+++	3 ppm/8h	1
Hydrogen Sulfide	gas	+++	systemic	+++	10 ppm/8h	1
Hydroquinone	solid	++	local systemic	++ ++	2 mg/m^3/8h	2
Hypochlorous Acid	liquid	++	local	+++	-	2
Indole	solid	++	local	+++	-	2
Iron Dust	solid	-	local	++	-	2
Isobutyl Alcohol	liquid	++	local systemic	+ ++	100 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Isobutyraldehyde	liquid	++	local systemic	+++ +	-	2
Isobutyric Acid	liquid	+	local systemic	+++ +	-	2
Isophorone	liquid	++	local systemic	++ ++	25 ppm/8h	2
Isophthaloyl Chloride	solid	+	local systemic	++ +	-	2
Isopropyl Acetate	liquid	++	local systemic	+ +	250 ppm/8h	2
Isopropylamine	liquid	++	local systemic	++ ++	5 ppm/8h	2
Isopropyl Ether	liquid	++	local systemic	++ +	250 ppm/8h	2
Kepone	liquid	++	local systemic	+ ++	-	2
Krypton 85 (radioactive)	gas	+++	systemic	+++	-	1
Lead Arsenate	solid	+	local systemic	+ ++	.5 mg/m^3/8h	2
Lead Fluoborate	solid	+	local systemic	++ ++	-	2
Lindane	solid	++	systemic	++	.5 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Malathion	liquid	++	systemic	+++	10 mg/m^3/8h	2
MCP	liquid	++	local systemic	+++ ++	-	2
Mercaptodimethur			systemic	++	-	2
Mercuric Cyanide	solid	+	local systemic	++ +++	.01 mg/m^3/8h	2
Mercuric Nitrate	solid	+	local systemic	++ +++	.05 mg/m^3/8h	2
Methacrylonitrile	liquid	++	local systemic	+ ++	1 ppm/8h	2
Methyl Acrylate	liquid	++	local systemic	+++ ++	10 ppm/8h	2
Methyl Amyl Acetate	liquid	++	local systemic	+ ++	50 ppm/8h	2
Methyl Amyl Alcohol	liquid	++	local systemic	++ +	25 ppm/8h	2
Methyl Bromide	liquid or gas	+	local	+++	20 ppm/8h	1
Methyl Chloride	liquid	+	local	+++	100 ppm/8h	2
Methylene Chloride	liquid	++	local systemic	++ ++	500 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Methyl Ethyl Ketone	liquid	++	local systemic	+ ++	590 mg/m^3/8h	2
Methyl Isobutyl Ketone	liquid	++	local systemic	+ +	100 ppm/8h	2
Methyl Mercaptan	gas	+++	local systemic	++ ++	10 ppm/8h	2
Methyl Methacrylate	liquid	++	local	+++	100 ppm/8h	2
Methyl Parathion	liquid	+++	systemic	+++	200 ug/m^3	1
Mexacarbate	solid	++	local systemic	+ +++	-	2
Monochloroacetone	liquid	++	local systemic	++ ++	-	2
Monochlorodifluoromethane	liquid	++	local (frostbite) systemic	+++ ++	1,000 ppm/8h	2
Monoethylamine	gas	+++	local	+++	10 ppm/8h	1
Monoisopropanolamine	liquid	++	local	++	-	2
Monomethylamine	gas	+++	local	+++	10 ppm/8h	1
Morpholine	liquid	++	local systemic	++ ++	20 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Mustard Gas	gas	++	local	+++	-	1
m-xylene	liquid	++	local systemic	++ +	100 ppm/8h	2
m-xylyl Bromide	liquid	++	local systemic	++ ++	-	2
Nabam	solid	++	local systemic	++ ++	-	2
Naled	liquid	++	local systemic	+ ++	3 mg/m^3/8h	2
n-amyl Acetate	liquid	++	local	++	100 ppm/8h	2
Naphthalene	solid	+	local systemic	++ ++	10 ppm/8h 50 mg/m^3/8h	2
Naphthenic Acid	solid	+	local	++	-	2
n-butyl Acetate	liquid	++	local	+	150 ppm/8h 710 mg/m^3/8h	2
n-butyl Acrylate	liquid	++	local	+++	-	2
n-butyl Alcohol	liquid	++	local systemic	++ +	50 ppm/8h	2
n-butyraldehyde	liquid	++	local	+++	-	2

TABLLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Nickel Ammonium Sulfate	solid	+	local	++	1 mg/m^3/8h	2
Nickel Carbonyl	liquid	++	local systemic	++ ++	.05 ppm/8h	2
Nitric Acid	liquid	+	local	+++	2 ppm/8h	1
Nitric Oxide	gas	++	local	+++	25 ppm/8h	1
Nitrilotriacetic Acid	solid	+	local	++	-	2
Nitrogen Dioxide	gas	++	local	++	5 ppm/15 min	1
Nitrobenzene	liquid	++	local systemic	++ ++	1 ppm/8h 5 mg/m^3/8h	2
Nitrogen Chloride	liquid	++	local	++	-	2
Nitroglycerine	liquid	++	local systemic	++ ++	2 mg/m^3/8h	2
Ozone	gas	+	local systemic	++ ++	.1 ppm/8h	2
Nitrous Oxide	gas	++	local	+++	25 ppm/8h	2
Nonane	liquid	++	local	++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Nonyl Phenol	liquid	++	local	+++	-	2
n-propyl Alcohol	liquid	++	local systemic	+ +	200 ppm/8h	2
Omazene	solid	+	local systemic	++ ++	-	2
o-nitrophenol	solid	++	local systemic	+++ +	-	2
o-nitroaniline	solid	+	local systemic	+ +++	-	2
Oxydipropionitrile	liquid	++	systemic local	++ +	-	2
o-xylene	liquid	++	local systemic	+ +	100 ppm/8h	2
para-nitroaniline	solid	+	local systemic	++ ++	1 ppm/8h	2
Pentanal	liquid	++	local systemic	++ +	-	2
Perchloromethyl mercaptan	liquid	+++	local systemic	++ ++	.1 ppm/8h	2
Phenolcarbylamine Chloride	liquid	++	local	++	-	2
Phenolmercuric Acetate	solid	+	local systemic	+ +++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Phosgene	gas	+	local	+++	.1 ppm/8h	1
White Phosphorous (yellow)	solid	+	local systemic	+++ ++	-	1
Phosphorous Oxychloride	liquid	++	local systemic	+++ ++	-	2
Phosphorous Pentasulfide	solid	+	local systemic	+++ ++	1 mg/m^3/8h	2
Phosphorous Trichloride	liquid	++	local systemic	+++ ++	.5 ppm/8h 3 mg/m^3/8h	2
Phthalic-Acid-Diethyl-Ester	liquid	++	local	+	-	2
Phthalic Anhydride	solid	+	local systemic	++ +	1 ppm/8h	2
p-nitrophenol	solid	+	local systemic	++ ++	-	2
Potassium Arsenate	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
Potassium Arsenite	solid	+	local systemic	++ +++	-	2
Potassium Permanganate	solid	+	local	+++	-	2
Propane	gas	++	local frostbite	+++	1,000 ppm/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Propargite			systemic	++	-	2
Propionaldehyde	liquid	++	local	+++	-	2
Propionic Acid	liquid	++	local	++	10 ppm/8h	2
Propionic Anhydride	liquid	++	local	+++	-	2
Propyl Acetate	liquid	++	local	++	200 ppm/8h	2
Propylamine	liquid	++	local systemic	+++ ++	-	2
Propylene	gas	+++	local	+	4,000 ppm/8h	2
Propylene Oxide	liquid	++	local	++	100 ppm/8h	2
p-xylene	liquid	++	local systemic	++ +	100 ppm/8h	2
Pyrethrin I	liquid	++	local (allergen) systemic	+ +	-	2
Pyrethrin II	liquid	++	local (allergen) systemic	+ +	-	2
Pyrethrum	solid	+	local (allergen) systemic	++ ++	5 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Pyridine	liquid	++	local systemic	++ +	5 ppm/8h	2
Pyrocatechol	solid	+	local systemic	++ +	1 ppm/8h	2
Quinhydrone	solid	+	local systemic	++ +	-	2
Quinine	solid	+	local systemic	+ +	-	2
Quinolene	liquid	++	local systemic	++ ++	-	2
Quinone	solid	+	local systemic	++ ++	.1 ppm/8h	2
Resorcinol	solid	+	local systemic	+++ ++	10 ppm/8h	2
Salicyaldehyde	liquid	++	local systemic	++ +	-	2
sec-Butylamine	liquid	+	local systemic	+++ ++	15 mg/m^3/8h	2
Selenium	solid	+	local systemic	++ ++	-	2
Selenium 75 (Radioactive)	solid	+	local systemic	++ +++	-	2
Sesone	solid	+	local systemic	++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Silver Nitrate	solid	+	local systemic	++ ++	-	2
Simazine	liquid	++	local systemic	+ +	-	2
Sodium Anthraquinone Sulfonate	solid	+	local	++	-	2
Sodium Arsenate	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
Sodium Arsenite	solid	+	local systemic	++ +++	.5 mg/m^3/8h	2
Sodium Bisulfite	solid	+	local	++	-	2
Sodium Borate	solid	+	local systemic	++ +	-	2
Sodium Butyldiphenyl Sulfonate	liquid	++	local	++	-	2
Sodium Decylbenzene Sulfonate		+	local systemic	+ ++	-	2
Sodium Fluoride	solid	+	local	++ +++	2.5 mg/m^3/8h	2
Sodium Fluorosilicate	solid	+	local	++	2.5 mg/m^3/8h	2
Sodium Hydrosulfite	liquid	++	local	+++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Sodium Hypochlorite	liquid	++	local	+++	-	2
Sodium Lauryl Sulfate	solid	+	local	++	-	2
Sodium Methylate	solid	+	local	++	-	2
Sodium Naphthalene Sulfate		+	local systemic	+ ++	-	2
Sodium Nitrite	solid	+	local systemic	++ ++	-	2
Sodium Octylsulfate	solid	+	local	+	-	2
Sodium Selenite	solid	+	local systemic	++ ++	.2 mg/m^3/8h	2
Strychnine	solid	+	local systemic	++ +++	.15 mg/m^3/8h .45 mg/m^3/15 min	2
Styrene	liquid	++	local systemic	++ ++	100 ppm/8h 125 ppm/8h	2 2
Sulfoxide	solid	+	local	+	-	2
Sulfur	solid	+	local	++	-	2
Sulfur Dioxide	gas	+++	local	+++	5 ppm/8h	1

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Sulfuric Acid	liquid	++	local	+++	1 mg/m^3/8h	1
Sulfur Monochloride	liquid	++	local	+++	1 ppm/8h	2
TBA	solid	+	local systemic	+ ++	-	2
T-Butylhydroperoxide	liquid	+	local systemic	+ ++	-	2
TCA	solid	+	local systemic	++ ++	-	2
TDE	solid	++	systemic	+	-	2
Tert-butylamide	solid	+	local systemic	+ +	-	2
Tetraborane	liquid	++	local systemic	+++ +++	-	2
Tetradecanol	solid	+	local systemic	+ +	-	2
Tetraethylene Pentamine	liquid	+	local systemic	++ ++	-	2
Tetraethyl Pyrophosphate	liquid	++	local systemic	+ +++	-	2
Thallium	solid	+	systemic	+++	0.1 mg/m^3/8h	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Thallous Nitrate	solid	+	systemic	+++	0.1 mg/m^3/8h	2
Thiophosgene	liquid	+	local	++	-	2
Thiram	solid	++	local systemic	++ ++	5 mg/m^3/8h	2
Titanium 44	solid	+	local	+	-	2
Titanium Chloride	solid	+	local	++	-	2
Toluene	liquid	+	local systemic	+ +	100 ppm/8h 375 mg/m^3/8h	2
Toluene diisocyanate	liquid	+	local systemic	++ ++	.02 ppm/8h .14 mg/m^3/8h	2
Toxaphene	solid	++	local systemic	+ ++	.5 mg/m^3/8h	2
Trichlorfon	solid	++	systemic	++	-	2
Trichloroethane	liquid	++	local systemic	++ ++	10 ppm/8h 45 mg/m^3/8h	2
Tricresyl Phosphate	liquid	++	local systemic	+ ++	-	2
Triethylaluminum	liquid	+	local	+++	-	1

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Triethylene Glycol	liquid	++	local systemic	+ ++	-	2
Triethylenetetramine	liquid	++	local	+++	-	2
Trimethylamine Gas	gas	++	local	+++	25 ppm/8h	1
Trimethylamine Solution	liquid	++	local	+++	25 ppm/8h	2
Trinitrotoluene	solid	++	local systemic	++ +	1.5 mg/m^3/8h	2
Uranyl Nitrate	solid	+	local systemic	++ ++	.25 mg/m^3/8h	2
Vanadium Oxytrichloride	liquid	++	local systemic	+++ ++	5 ppm/15 min	2
Vapam	liquid	++	local systemic	++ +	-	2
Vinyl Acetate	liquid	++	local	++	10 ppm/8h 30 mg/m^3/8h	2
Vinyl Bromide	gas	+++	local systemic	+++ +++	200 ppm/8h	1
Vinyl Chloride	gas	+++	local systemic	+++ +++	200 ppm/8h	1
Vinyl Ether	liquid	++	local systemic	++ ++	-	2

TABLE III-1 (CONTINUED)

DERMAL TOXICITY

Chemical	Physical State	Skin Penetration	Dermal Toxicity	Potency	Permissible Concentration	Category
Xenon 133 (radioactive)	gas	+++	systemic	+++	-	1
Zinc Borate	solid	+	local	++	10 mg/m^3/8h	2
Zinc Chloride	solid	+	local	++	1 ppm/8h	2
Zinc Cyanide	solid	+	local systemic	+ +++	-	1
Zinc Hydrosulfite	solid	+	local	+++	-	2
Zinc Phenolsulfonate	solid	+	local	+++	-	2
Zinc Phosphide	solid	+	local systemic	++ ++	-	2

APPENDIX E

MANUAL

OCCUPATIONAL
HEALTH AND SAFETY

CHAPTER 10

EPA DIVING SAFETY POLICY

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1. PURPOSE. This Chapter establishes Agency policy regarding commercial diving operations in accordance with Department of Labor, Occupational Safety and Health Administration regulations at 29 CFR 1910, Subpart T. Its purpose is to assure that all diving operations, performed under the auspices of EPA, are conducted in a safe manner, according to uniform procedures, and by sufficiently trained personnel. This Chapter establishes Agency procedures for developing and administering such standard safety practices.

2. SCOPE. The requirements and procedures specified in this Chapter shall apply to all diving operations involving any project of the Agency and carried out by any employee, either temporary or permanent, of the Agency during the course of his/her employment. In addition, these requirements shall also apply to any visiting non-Agency employee engaged in a joint diving operation at, or under the auspices of, any Agency facility to the extent that this person is not governed by comparable requirements of the Agency or institution that he/she represents. This Chapter applies regardless of ownership of equipment, and any equipment used in conjunction with Agency diving operations regardless of ownership, shall conform to the provisions of this Chapter. This Chapter shall apply to any type of open circuit SCUBA diving operation, including but not limited to: research projects, monitoring projects, sample collections, or equipment maintenance, with the only exception being the handling of an actual emergency situation. It is not the intent of these provisions to delay or hamper an actual rescue operation; therefore, it is the responsibility of the Unit Diving Officer or Dive Supervisor at the scene to determine the ultimate course of action during a particular emergency and by doing so, must not aggravate the situation or jeopardize the safety of additional personnel.

3. ADMINISTRATION. The Assistant Administrator for Administration shall broadly administer the Agency's Diving Safety Program through the Occupational Health and Safety Staff (OHSS).

a. Designation. The Occupational Health and Safety Staff, upon the advice of the EPA Diving Safety Committee, shall administer the Agency's Diving Safety Program and coordinate safety policy and procedures.

b. EPA Diving Safety Committee.

(1) Composition. The EPA Diving Safety Committee shall be composed of the following members:

(a) Chairman selected or voted on by Committee Members;
(b) Active EPA Diving Officers; and
(c) OHSS Safety Programs Manager.

(2) Revisions. All recommendations for revisions of the regulations must be agreed upon by EPA Diving Safety Committee.

(3) Responsibilities. The EPA Diving Safety Committee shall be responsible for:

(a) Recommending policy and changes in operating procedures within EPA that will ensure a safe and efficient diving program;

(b) Reviewing existing policies, procedures, and training needs to ensure a continually high level of technical skills and knowledge throughout the EPA diving program;

(c) Planning, programming, and directing, in cooperation with the OHSS, matter of policy pertaining to the initial certification of new divers and refresher training of experienced divers;

(d) Recommending changes in operating policy to the Director, Ocupational Health and Safety Staff and the Assistant Administrator for Research and Development, and Regional Administrators;

(e) Serving as an appeal board in cases where a diver's certification has been suspended;

(f) Planning, programming, and developing diver workshops, seminars, and other activities considered essential to maintaining a high level of competency among divers;

(g) Reviewing EPA diving accidents or potentially dangerous experiences and reporting on preventive measures to ensure the avoidance or reoccurrence of incidents; and

(h) Meeting, at least, annually to discuss recommendations and proposed actions.

In addition, members may participate in the Safety Officer/Designees Annual Meeting.

c. Diving Safety Committee Chairman. The Committee will select or vote for a chairman to represent them and act as focal point on all EPA diving activities.

(1) Qualification. The Chairman shall:

(a) Be a trained diver with a wide range of experience;
(b) Be a currently certified EPA diver;
(c) Have a least 5 year's experience as a diver; and
(d) Have successfully completed a nationally recognized instructors certification course or it's equivalent.

(2) Responsibilities.

(a) Issue through OHSS, EPA Diver Certification to qualified employees based on recommendations and data from the unit diving officer;

(b) Coordinate with OHSS, and Diving Safety Committee training certification and other safety programs for divers;

(c) Confer with OHSS Industrial Hygienist Manager on the approval and use of specialized breathing apparatus or mixture of gases;

(d) Review and initiate through OHSS, appropriate action on recommendations made by the Diving Safety Committee; and

(e) Remain abreast of new diving techniques, procedures and equipment.

d. Unit Diving Officer.

(1) Designation. Unit Diving Officers shall be selected from various EPA installations which conduct diving operations. These diving officers shall be appointed by the installation director.

(2) Qualifications. The Unit Diving Officer shall be a trained, currently certified diver experienced in the types of diving conducted by the organizational unit.

(3) Responsibilities. The Unit Diving Officer shall be responsible, within the unit, for:

(a) Ensuring that all diving gear and accessory equipment be maintained in a safe operating condition;

(b) Ensuring the maintenance of equipment files at the reporting unit levels, to include type, brand name, serial number, and repairs completed on compressors, tanks, regulators, depth gauges, pressure gauges, watches, helmets, hoses, pneumometers and decompression meters;

(c) Ensuring that a competent Dive Supervisor is in charge of the diving operations conducted by the unit's various operations;

(d) Reporting immediately all diving related accidents which occur within his unit on EPA Form 1440-9 and other appropriate accident reports as outlined in Chapter 3 of this Manual to the Occupational Health and Safety Staff through the local Safety Officer/Designee;

(e) Maintaining a file of each diver in the unit, or delegating the responsibility to the Dive Supervisor. Files shall include but not be limited to: diving physical exams (subject to the requirements of the Privacy Act of 1974), training records, letters of certification, and monthly dive logs, etc; and

(f) Dive plan/log information.

e. Dive Supervisor.

(1) Designation. Depending on the unit organization, a Dive Supervisor will be assigned for each operation by the Unit Diving Officer.

(2) Qualification. The Dive Supervisor shall be a currently certified diver experienced in that specific type of diving.

(3) Responsibilities. The Dive Supervisor shall be in complete charge of the individual diving operation as a member of the dive team at the location of the dive, and shall be responsible for and ensure that:

(a) All diving operations are conducted safely in accordance with prescribed EPA diving safety rules and regulations;

(b) All divers are certified, properly trained, and physically fit to perform the required diving, and that the prescribed files on the divers are maintained if the responsibility has been delegated by the Unit Diving Officer;

(c) All equipment is in a safe operating condition, and that the required maintenance records are maintained as directed by the Unit Diving Officer;

(d) Dives are terminated when, in his/her opinion, significant environmental, personal, or equipment problems are encountered and emergency aid is summoned;

(e) Emergency procedures are understood by all personnel prior to diving;

(f) All divers are monitored after each dive for symptoms of decompression sickness; and

(g) He/she is knowledgeable in dive plan and overall operation to be performed.

f. Individual Diver.

(1) Designation. Individual divers shall be certified by the EPA Diving Safety Committee Chairman upon recommendation from the Unit Diving Officer.

(2) Qualifications. Divers shall be sufficiently trained to undertake the assigned diving tasks.

(3) Responsibilities. The individual diver shall be responsible for and ensure that:

(a) A good physical condition and a high level of diving proficiency are maintained;

(b) The equipment is in a safe operating condition;

(c) Diving conditions are safe; and

(d) The dictates of training or diving regulations are not violated.

g. Tender.

(1) Designation. The Dive Supervisor will select the Tender to be used for a specific dive. His/her name will appear on the Dive Plan/Log and will, therefore, be approved beforehand by the Unit Diving Officer.

(2) Qualifications. The Tender need not be a currently EPA Certified diver, but must, in the opinion of the Dive Supervisor and the Unit Diving Officer, have sufficient knowledge of basic first aid, swimming, life saving, boat operation and other procedures to be used in an emergency.

(3) Responsibilities. The Tender will perform the following:

(a) Assist the divers, as requested, in putting on or taking off equipment;

(b) Record in writing the "down" and "up" times of all divers on the team;

(c) Maintain a constant visual observation of the diver's exhaust bubbles and,

1 warn off boat traffic which may pose a hazard to the submerged divers;

2 in larger vessels, advise the vessel operator as to the location of the divers and their readiness for being retrieved;

(d) Assist the divers, as requested, in exiting the water; and

(e) Perform no other concurrent function which will interfere with the conduct of the above duties.

4. POLICIES.

a. Individual Diver Responsibility. Each diver has the responsibility and privilege to refuse to dive if diving conditions are unsafe or unfavorable; if at any specific time, the diver feels that he or she is not in good physical or mental condition for diving; or if by diving, the diver would violate the dictates of training or these regulations. The conditions and reasons for refusing to dive may be required to be documented. If requested, the incident will be reviewed by the officer in charge of the Reporting Unit with the Unit Diving Officer and diver, and appropriate action may be taken. Any action resulting from this review may be appealed to the EPA Diving Safety Committee.

b. SCUBA Diving Teams. Except under emergency conditions, the buddy system of at least two (2) divers will always be required. In the event that diving is shallow within a restricted area, with water conditions of low velocity and turbidity, the buddy diver may remain at the surface fully equipped, maintaining visual, verbal and/or physical contact with the working diver at all times. A surface attendant shall be in the immediate area any time diving conditions require it.

c. Diver Proficiency. EPA certified divers should log an average of at least two (2) diving days per month. Any time six (6) weeks or more elapses without a dive, the diver should complete a requalifying program. Any time three (3) months or more elapses without a dive, the diver must complete a requalifying program before resuming work dives. The EPA Diving Safety Committee Chairman, with the advice of the Diving Officer or designee, shall specify the requalifying program. This requirement may be waived by the official in charge of the project, program, or Reporting Unit during emergency conditions. A report of such waiver must be submitted to the Office of Occupational Health and Safety Staff through the Unit Diving Officer for review by the EPA Diving Safety Committee. Supervisors will authorize the necessary time and payment for qualifying dives if diving is required for official program activities. Diving equipment will be available during nonduty hours for purposes of maintaining diver proficiency.

5. DIVER TRAINING AND CERTIFICATION.

a. Training.

(1) Basic. All prospective EPA divers must have successfully completed a basic diver training course offered by one of the nationally recognized private agencies (e.g. NAUI, PADI, YMCA, NASDS) or by the U.S. Navy. Training courses givey by colleges or universities must be approved for content by the EPA Diving Officer before being accepted for this requirement.

(2) National Oceanic and Atmospheric Administration (NOAA) Training. All working divers, senior divers and diving instructors shall attend the NOAA "Diving Accident Management" class within 1 year of adoption of this Chapter.

b. Medical Requirements.

(1) Prior to acceptance for initial diver training or certification, and annually thereafter, each diver shall be required to undergo a diving physical examination. The individual diver shall provide the examining physician with the following listed NOAA medical forms, as appropriate, in order to ensure an examination appropriate to diving activities:

(a) NOAA Form 64-5, Part I, Medical Evaluation Criteria;
(b) NOAA Form 64-5, Part II, Diving Fitness Medical Evaluation Report;
(c) SF-78, Certification of Medical Examination (Civilian Personnel);
(d) SF-88, Report of Medical Examination (Commissioned Personnel); and
(e) SF-93, Report of Medical History.

(These forms are available from the local Safety Officer/Designee.)

(2) Upon receipt of the completed medical documents from the examining physician, the individual diver is responsible for distribution of these forms as follows:

(a) Forward signed originals of SF-78 to the EPA Diving Safety Committee Chairman through the Unit Diving Officer, with copies to OHSS;

(b) Forward a signed copy of NOAA Form 64-5, Part II, only, to the Unit Diving Officer for retention in the employee's file; and

(c) Retain a copy of all forms for personal records and to provide additional copies should the originals be lost in transmittal.

(3) Signed copies of NOAA 64-5, Part II, marked "Approved" shall, upon screening of documents for completeness, substantiate medical qualifications for diving.

(4) In any instance where an employee does not meet established physical standards, or in any instance where there is a question about en employee's medical qualifications for diving, the EPA Diving Safety Committee Chairman may consider a waiver based on a review of the case by an expert selected by the EPA Medical Monitoring Program Manager, who shall render its medical opinion and recommendations in a timely manner.

(5) Based upon the opinion and recommendations of the medical expert selected by the Medical Monitoring Program Manager, the EPA Diving Safety Committee Chairman shall:

(a) Refuse waiver;

(b) Approve waiver and certify fitness for full diving duty; or

(c) Approve waiver and restrict diving duty as appropriate.

This designation shall only be made for conditions that are not significantly disabling and do not constitute a significant threat to the employee or fellow divers.

(6) No waiver of any portion of established medical evaluation criteria shall be granted without further consultation with the Medical Monitoring Manager. If, after consultation, a waiver is granted, the Diving Safety Committee Chairman shall be notified in writing 30 days prior to the commencement of the waiver, stating the reasons for granting the waiver.

c. Certification. The Unit Diving Officer submits the prospective diver's record of qualifications to the EPA Diving Safety Committee Chairman for final review. Copies of the following should be included:

(1) Present certificate;
(2) The physician's Diving Fitness Medical Evaluation Report;
(3) The results of other tests conducted by the Unit Diving Officer;
(4) A written statement of the Unit Diving Officer's evaluation of the overall qualifications and performance of the prospective diver;

(5) An EPA certification issued by the Unit Diving Officer in one of the following categories:

(a) Trainee Diver. A diver who has completed a basic SCUBA diver training course but has performed fewer than 15 open water dives. Diver Trainees may not be paired together to form a dive team nor may they perform working dives. They may accompany a working diver as a buddy on dives involving a simple task, at the discretion of the Unit Diving Officer.

(b) Working Diver. A diver who has completed a least 15 open water dives, but who otherwise may have limited or infrequent experience or at the judgement of either the EPA or Unit Diving Officer should be restricted in his/her activities. A limited diver may perform working dives within his/her restriction or abilities.

(c) Senior Diver. A diver who has demonstrated a high level of competence, good judgement, and considerable experience and who has logged at least 100 dives. The unlimited diver shall be capable of serving as the Dive Supervisor on a given dive.

(6) At the recommendation of the Unit Diving Officer, along with supporting documentation, the EPA Diving Safety Committee Chairman will issue new classifications as appropriate.

d. Reciprocity. In order to encourage and facilitate joint operations between EPA facilities and neighboring colleges, universities, private institutions, or other government agencies, the Unit Diving Officer may approve such dive plans upon inspection of the credentials of the prospective non-EPA diver, providing the criteria for certification of that diver by the institution he/she represents is comparable to those in this Manual. The visiting diver must also have permission from his/her diving officer and must be covered by an accident insurance plan by his/her institution. Questions in this matter should be directed to the EPA Diving Safety Committee.

6. DIVING OPERATIONS.

a. Certification. Each diver who is an employee of the U.S. Environmental Protection Agency must have an EPA certification at the level of the dive being conducted. Each non-EPA diver engaged in a dive under the auspices of any EPA facility must have a certification comparable to EPA certification from the institution he/she represents on file with the Unit Diving Officer.

b. Limits.

(1) All dives shall employ open circuit SCUBA using compressed air unless otherwise specifically approved by the Unit Diving Officer in writing.

(2) All dives shall be within the no decompression limits as specified in the U.S. Navy Decompression Tables. When there is a need for dives beyond this limit the dives must be approved in advance by the Diving Safety Committee.

(3) No solo diving will be permitted.

(4) No diving will be conducted without the submittal and authorization of a Dive Plan.

(5) No dive exceeding the 130 foot depth will be permitted in the absence of a working decompression chamber attended by trained personnel.

(6) Cave and under ice diving will generally not be permitted. Submit all requests to the Unit Diving Officer and forward copies to the Diving Safety Committee Chairman.

(7) Dives in waters of great depths, where the diver is not in visual contact with the bottom (over bottom dives) and where a diver could lose his/her orientation or descend beyond safe limits, will be conducted with some provision for direct contact with the surface such as a buoyed weighted line with depth markings.

c. Dive Teams. A standard SCUBA diving team shall consist of a minimum of 3 members: the Dive Supervisor, the diver buddy, and the Tender. Some situations may require a third diver in the water, but at no time shall any diver in the water lose visual or tactile contact with at least one other diver. If such contact is lost, all divers must immediately surface. In the situation requiring diving from a boat, the vessel operator's principle responsibility is for the safety of his/her vessel and its occupants. Hence, depending on the size of the vessel and the conditions, it may be deemed inappropriate by the Unit Diving Officer, the Dive Supervisor, or the vessel operator, for the latter to serve also as the Tender. When this is the case, the Dive Supervisor will advise the vessel operator as to the safety precautions specified in this Chapter. At the discretion of the Unit Diving Officer, a single diver may enter the water if line tended from the surface. However, a fully equipped stand-by diver must be at the dive site ready to give immediate assistance.

d. Equipment. All items of equipment shall be visually and operationally inspected before each actual use and must be in proper operating condition. All dive team members shall be familiar with their use. The following equipment shall be present at the dive site for all dives.

(1) Personal equipment.

(a) Flotation/Buoyancy Compensation Device - Each diver must wear an adequate flotation device capable of being filled by at least two methods.

(b) Tank Harness and Weight Belts - must have a quick release mechanism.

(c) Tank Pressure Gauge - must be worn at all times and monitored frequently.

(d) Depth Gauge - shall be worn by each diver when diving in unfamiliar territory, at unknown depth, in areas of great tidal fluctuation, in areas of uneven bottom, or under any other conditions which might cause the diver to exceed his/her planned depth. It is recommended that a depth gauge be worn during all diving operations.

(e) Diving Watch - shall be worn by each diver in situations where there is any likelihood of exceeding the no decompression limit.

(f) Decompression Meter - shall not be used in lieu of proper planning of the dive and timekeeping at the dive site.

(g) Compass - shall be worn by each diver. Divers can become disoriented in direction at any depth.

(2) Support Equipment.

(a) Dive Flag - an appropriate dive flag shall be shown at all times. This is especially critical while actively diving in areas subject to boating or other hazardous traffic or when required by local regulation. An appropriate dive flag is a square red flag with a white diagonal stripe at least 12" square (depending on the size of the vessel) in all waters except those frequented by international traffic. In this case, the international code flag "Alpha" will be also used. In any case, divers will make every effort to avoid diving in areas in which traffic would cause a safety hazard.

(b) First Aid Kit - shall be approved by the Unit's physician who performs the annual physicals. A copy of the American National Red Cross publication, Standard First Aid and Personal Safety shall be included and a copy of the NOAA/Sea Grants Book, First Aid for Boaters and Divers. Also emergency oxygen should be on board.

(c) Ladder - shall be provided when diving from a vessel, dock or other surface where elevation above the surface of the water presents a difficulty to the diver. The ladder must extend sufficiently below the surface of the water to support the diver while still in the water.

(d) Safety Plan - a copy of this Diving Safety Chapter, the U.S. Navy Decompression Tables and emergency aid information shall be present at each dive site.

(e) Communications - at each dive site, shore or vessel, located beyond the range of other reasonable voice communication, a 2-way radio will be provided for use in summoning emergency aid.

(f) Additional support tanks-should be on board and be available.

(g) Underwater transponder/communicator should be on board.

e. The Dive Plan/Log. Divers are required to log all dives. The EPA Diving Plan/Log will be initiated by the prospective Dive Supervisor desiring to conduct a dive and submitted to the Unit Diving Officer for approval. After the dive is completed, details of the dive will be recorded and the Dive Supervisor will certify that the regulations of the Manual were adhered to and submit it each month to the Unit Diving Officer.

1. Certification. Each diver must have a valid EPA certifiation or EPA equivalent.

2. Solo Diving. No one may dive unattended.

3. Depth Limits. Dives shall not exceed 130 feet. Proposals for planned dives to depths greater than 130 feet will require written approval by the Unit Diving Officer or designee.

4. Decompression Tables. Decompression tables should be copied for use by a photographic method which reproduces an exact copy. If this method is not available, then the hand copied schedules should be checked for accuracy and signed by several persons.

5. Decompression Dives. Diving activities which exceed the limits of no-decompression must be approved in advance by the EPA Diving Committee.

6. Over-Bottom Dives. Dives in waters where a diver could sense a loss of orientation or descend below safe diving depths are to be considered over-bottom dives. No over-bottom dives shall be made unless some direct contact with the surface is maintained, such as net web, a marked line suspended from a surface float, or depth gauges for all participants, which permits the diver to determine whether ascension or descension occurs. All such divers must be equipped with a buoyancy compensating device.

7. Boat Tending. During dives beyond swimming distance from shore or those in areas of strong currents, a small boat with a qualified operator will tend the diver.

8. Recompression Chamber. The location, availability and telephone number of all accessible and operable recompression chambers shall be maintained by the dive supervisor who instructs the dive team.

9. Emergency Procedures. The Unit Diving Officer, with the approval of the EPA Diving Safety Committee, will prescribe emergency procedures to be used in handling diving-related accidents in the operational area, and all divers shall be familiar with these procedures. All emergency lists and procedures shall be available at the dive location.

10. First Aid Training. All divers should have appropriate First Aid and CPR training.

11. Equipment.

a. Life Support. Open circuit SCUBA using compressed air shall be standard. Other types of equipment (i.e., surface-supplied diving equipment, closed-circuit rebreathers, semiclosed units or other types of diving apparatus utilizing gas mixtures) may be approved for use by the Diving Safety Committee Chairman. Individuals requesting use of closed-circuit rebreathers, semiclosed units, or other types of equipment must have been trained and qualified in the use of such equipment. Dive supervisors shall also be trained in the use of such equipment and shall be ready to assist in case of an emergency.

b. Harness and Weight Belt. All harness and weight belts must have a quick release, operable by a single motion by either hand.

c. Flotation Device. Each diver shall wear an adequate inflatable vest or other flotation device.

d. Compass. An underwater compass shall be carried by each diver when, in the opinion of the Dive Supervisor, lack of underwater orientation is likely to occur and may create a hazard.

e. Depth Gauge. One underwater depth gauge shall be carried by each diver when diving in an area of unknown depth or an area of uneven bottom contours when a diver might reasonably exceed the planned dive depth.

f. Decompression Meter. Use of decompression meters will be authorized only by the Diving Safety Committee Chairman. Decompression meters will not be used for dives which require decompression stops. Decompression meters can be used as an alternative method of determining the allowable time at depths before a decompression stop is required. In all cases at least two meters must be used simultaneously with the more conservative meter used to determine the allowable dive time. Decompression meters must be recalibrated every eighteen (18) months by a qualified technician.

g. Diving Watch. A diving watch shall be worn by each member of a diving team.

h. Diving Flag. A diving flag shall be shown while actively diving in areas subject to boating or other hazardous traffic.

i. Air Compressor. No person shall operate a SCUBA air compressor without having first read the instructions and assisted an operator experienced in its operation. An operational log shall be maintained for all EPA SCUBA compressors.

12. Equipment Maintenance. All diving gear and accessory equipment shall be maintained in a safe operating condition. Manufacturers recommended servicing policy shall be followed. Equipment in questionable condition shall be repaired, overhauled, or discarded. All regulatory valves, depth gauges, and decompression meters must be critically examined, calibrated, or checked for accuracy by a competent mechanic or appropriate specialist every eighteen (18) months. A record of the inspection and repair will be filed with the Unit Diving Officer.

13. Air Tank Inspection and Testing. The interior of all cylinders must be visually inspected annually by a trained person; cylinders shall be hydrostatically tested at least every three (3) years. The date of the last test must be recorded on the tank.

14. Air. Tanks shall be charged only with air certified as meeting established air standards.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL RESEARCH LABORATORY
SABINE ISLAND
GULF BREEZE, FLORIDA 32561

EPA Diving Physical Examination Checklist

Jim Patrick
Diving Supervisor

Name of Diver ______________________ Date ____________

Organization ______________________________________

A copy of all physical examination reports will be submitted to the Unit Diving Officer.

Physical examinations should be reported on the following:

☐ 1. Report of Medical Examination, SF-88.

☐ 2. Report of Medical History, SF-93.

All reports should be COMPLETE as described by NOAA Diving Medical Evaluation Criteria (keyed to SF-88), with PARTICULAR ATTENTION to:

☐ 3. 12 Lead Resting EKG - Required for initial certification and annually after age 35.

☐ 4. Audiogram - Required for initial certification and every 5 years thereafter.

☐ 5. Chest X-ray - Required for initial certification, bi-annually until age 40, and annually thereafter.

☐ 6. **Blood Pressure - Required for all examinations.**

☐ 7. **Height and Weight - Required for all examinations.**

☐ 8. **SF-88 Item #77A marked qualified for diving.**

☐ 9. Date of Physical - Required on all report forms.

☐ 10. Signature - Required on ALL report forms; all signature blocks for both the examining physician and the examinee should be completed.

I have reviewed the attached physical examination report and consider it to be complete. There are no obvious omissions nor obvious inconsistencies with the NOAA Diving Medical Evaluation Criteria.

____
Signature of UDO Date

NDO DIVER INFORMATION SUMMARY

☐ NOAA ☐ Non-NOAA: ______________________
Name of Agency

☐ NOS ☐ HQ
☐ NMFS ☐ ERL

____
Name of Diver

____
Name of UDO

____
Date of Birth

____
Certification Level

____
Blood Type & RH Factor

____
Date of Certification

TRAINING & CERTIFICATIONS:

Operational: ______________________
Dry-Suit: ______________________
Divemaster: ______________________
Chamb. Oper: ______________________
EMT: ______________________
Polluted Water: ______________________
Surface Supplied: ______________________
Mixed Gas: ______________________
Open Bell: ______________________
Other: ______________________

DATE OF LAST:

Physical	Chest X-ray	EKG	Audiogram

NOTES: ______________________

DIVER RESUME

Name____________________

Date____________________

1. Formal Training (date, location, certification):

2. Special qualifications (ex. UDT, EOD, instructor):

3. Other Training (ex. mixed gas, rebreather, saturation):

4. Types of diving-equipment used (ex. rebreather, diving bell, full-face mask):

5. Diving conditions experienced (ex. ice, cave, low visibility):

6. For each year you have been diving, list the approximate total number of dives and total bottom time you have completed (ex. 1970 - 20 dives - 10 hrs.):

7. Name and address of persons who can attest to your diving ability and experience:

8. Other relevant information:

PART I
MEDICAL EVALUATION CRITERIA

Reproduced from
best available copy.

These criteria are to be used by the examining physician in evaluating an applicant's physical fitness for diving.

Clinical Evaluation: The applicant should be free of chronic disabling disease or disability. His history should be free of disease or disability of the type which could recur under diving conditions, or strenuous physical activity. Any disease which might prevent active exercise should disqualify the applicant. There should be no bleeding tendency.

Ears: Individuals with acute or chronic ear infection should not dive. Scarring from otitis is not a contraindication to diving. Individuals with perforation of the drum should be disqualified. Healed perforations of the drum of at least two months duration will not be disqualifying. Special care should be taken to keep the ears well cleared during the dive. Acute or chronic otitis externa with discharge, or moderate amounts of cerumen in the external canal, should be considered harmful in diving until the canals are clear. Check tympanic movement with Valsalva. There should be no disease of the mastoids or disturbances in equilibrium.

Audiogram Tracing: This should be done on each applicant to rule out preexisting hearing losses in frequency ranges which could be further impaired by diving. Damage to the drum from diving could further compromise a hearing loss. Chronic otitis externa, a common infection in divers, may thicken the ear drum and thereby increase the hearing loss. This examination should be done as a baseline and repeated every five years if diving routinely. It should be done often if injury occurs to the ears or symptoms referable to any ear structures develop.

Nose and Sinuses: Persons having acute or chronic sinus trouble should not dive unless free drainage of the sinuses is assured. Congestion, secondary to upper respiratory infection or hay fever, is a contraindication to diving until free passage of air is possible. Persons with acute upper respiratory infections may be passed, but should be strictly cautioned against diving until the upper respiratory infection has completely cleared.

Mouth and Throat: Bridgework or dentures should fit solidly. The applicant should be capable of retaining a diving mouthpiece. Acute infectious diseases of the soft tissue of the oral cavity are disqualifying until remedial treatment is completed.

Vascular: Peripheral vascular disease which might interfere with gas exchange in an extremity should disqualify the applicant. Varicose veins or hemorrhoids should be minimal or absent.

Heart: Thrust, size, rhythm, and sounds should be normal.

EKG: Divers should have on record an initial normal exercise electrocardiogram. Beyond age 40, an exercise electrocardiogram should be performed annually.

Blood Pressure: Blood pressure should not exceed 145 millimeters systolic, or 90 millimeters diastolic on repeated examinations for unrestricted diving.

Pulse: Pulse should be normal.

Lungs and Chest: Persons with evidence of chronic lung disease, interference with free air passage, or with poor gas exchange, should be disqualified. A history of asthma, with no attacks in the preceding three years, should not disqualify the applicant from diving, as long as there is no residual evidence of the disease. A vital capacity test is necessary only when the examiner is clinically suspicious of a disease. A history of pneumothorax or thoracotomy shall disqualify the applicant.

Chest X-ray: A report of a 14 x 17 chest x-ray, taken within 12 months prior to this physical, shall be normal and the results reported with this examination.

Gastrointestinal: Persons having symptomatic acute or chronic gastrointestinal disease, including ulcers, shall be disqualified.

Serology: Should be performed because of equipment sharing.

Hemoglobin and Red and White Blood Cells: Should be within normal limits.

Blood Type and RH Factor: Required on first examination only.

Neuromuscular: The applicant should be able to demonstrate fine and gross muscular coordination. Reflexes should be normal. Joints should be free from disabling arthritic conditions.

Endocrine: Endocrine disturbances shall disqualify the applicant.

Neuropsychiatric: Neuropsychiatric disturbances may disqualify the applicant. This area is obviously most difficult to evaluate. If the response of the patient to stress is questionable, seriously consider disqualifying him. Emergencies below the surface require cool judgment. The alternative is death, perhaps for others. Emotional immaturity or instability and recklessness are serious liabilities, not only for the person contemplating diving, but also for his companions. Anyone exhibiting poor temperament should be disqualified. Claustrophobia, as well as other phobias, inability to tolerate face masks, accident proneness, etc., should be included as poor temperament. Screen for history of headache, dizziness, fainting spells, soaking sweats, dyspnea, palpitations, stuttering, attempted suicide, sleepwalking, disciplinary problems. Elicit feelings about: living in a restricted environment, possibility of bodily harm, lack of privacy, separation from home and family. Observe appropriateness of emotional reactions during examination.

Alcoholism, unusual use of drugs, medicines, intoxicants, or drug addiction shall disqualify the applicant.

Central Nervous System: History of syncope, epilepsy, convulsions, organic disease of the central nervous system or history of head injury with sequelae shall disqualify the applicant.

All abnormalities of the cranial nerves, deep tendon reflexes, balance, position discrimination, sensation or coordination (including gait) should be recorded in detail.

Skin: The skin should be free of active, acute, or chronic disease which may prove undesirable from the standpoint of equipment sharing.

Visual Acuity: A normal ophthalmoscopic and extra-ocular musculature examination shall be given. Although vision for distant objects under water is often decreased by particulate matter in the water, and the low levels of illumination that may be encountered, the refractive changes introduced by the water environment enlarge objects by about one-fourth. The examining physician and the MLC Diving Officer should, in each instance, determine whether the applicant's visual status is compatible with safety during diving. The following criteria may be helpful as a guide in rendering this decision:

a. Individuals with uncorrected vision of 20/50 or better for near and distant in one or both eyes, and with no evidence of organic ocular disease are unrestricted.

b. Individuals with uncorrected visual acuity of 20/50 to 20/100 for distance and the equivalent of 20/50 or better for near in one or both eyes, and with no evidence of organic ocular disease, may dive if the applicant is advised of the risks associated with the restricted vision.

c. Applicants with uncorrected vision of less than 20/100 for distance and less than 20/50 for near, in one or both eyes, and with no evidence of organic ocular disease should be restricted from diving unless optical correction worn underwater improves vision to 20/100 or better for distance, and 20/50 or better for near, in one or both eyes. These individuals should be advised of the risks associated with decreased vision.

d. Applicants with significant organic ocular disease affecting both eyes should be restricted from diving.

Height/Weight: The applicant should not be obese. His height and weight should be within the limits of the following chart:

Height (inches)	Max. Weight	Height (inches)	Max. Weight	Height (inches)	Max. Weight	Height (inches)	Max. Weight
64	164	68	184	72	205	76	230
65	169	69	189	73	211	77	236
66	174	70	194	74	218	78	242
67	179	71	199	75	224		

☆ U.S.GPO:1979-665-010/1022-6

Standard Form 88
Revised 10/75
General Services Administration
Interagency Comm. on Medical Records
FPMR 101-11.806-8

REPORT OF MEDICAL EXAMINATION

1. LAST NAME—FIRST NAME—MIDDLE NAME	2. GRADE AND COMPONENT OR POSITION	3. IDENTIFICATION NO.
4. HOME ADDRESS (*Number, street or RFD, city or town, State and ZIP Code*)	5. PURPOSE OF EXAMINATION	6. DATE OF EXAMINATION

7. SEX	8. RACE	9. TOTAL YEARS GOVERNMENT SERVICE		10. AGENCY	11. ORGANIZATION UNIT
		MILITARY	CIVILIAN		

12. DATE OF BIRTH	13. PLACE OF BIRTH	14. NAME, RELATIONSHIP, AND ADDRESS OF NEXT [illegible]
15. EXAMINING FACILITY OR EXAMINER, AND ADDRESS		16. OTHER INFORMATION
17. RATING OR SPECIALTY		TIME IN THIS CAPACITY (*Total*) / LAST SIX MONTHS

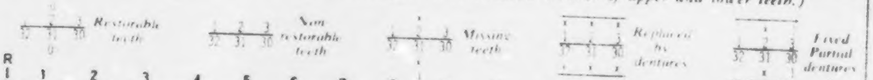
CLINICAL EVALUATION

NORMAL	(*Check each item in appropriate column, enter "NE" if not evaluated.*)	ABNORMAL
	18. HEAD, FACE, NECK AND SCALP	
	19. NOSE	
	20. SINUSES	
	21. MOUTH AND THROAT	
	22. EARS—GENERAL (*Int. & ext. canals*) (*Auditory acuity under items 70 and 71*)	
	23. DRUMS (*Perforation*)	
	24. EYES—GENERAL (*Visual acuity and refraction under items 59, 60 and 67*)	
	25. OPHTHALMOSCOPIC	
	26. PUPILS (*Equality and reaction*)	
	27. OCULAR MOTILITY (*Associated parallel movements, nystagmus*)	
	28. LUNGS AND CHEST (*Include breasts*)	
	29. HEART (*Thrust, size, rhythm, sounds*)	
	30. VASCULAR SYSTEM (*Varicosities, etc.*)	
	31. ABDOMEN AND VISCERA (*Include hernia*)	
	32. ANUS AND RECTUM (*Hemorrhoids, fistulae*) (*Prostate, if indicated*)	
	33. ENDOCRINE SYSTEM	
	34. G-U SYSTEM	
	35. UPPER EXTREMITIES (*Strength, range of motion*)	
	36. FEET	
	37. LOWER EXTREMITIES (*Except feet*) (*Strength, range of motion*)	
	38. SPINE, OTHER MUSCULOSKELETAL	
	39. IDENTIFYING BODY MARKS, SCARS, TATTOOS	
	40. SKIN, LYMPHATICS	
	41. NEUROLOGIC (*Equilibrium tests under item 72*)	
	42. PSYCHIATRIC (*Specify any personality deviation*)	
	43. PELVIC (*Females only*) (*Check how done*) ☐ VAGINAL ☐ RECTAL	

NOTES (*Describe every abnormality in detail. Enter pertinent item number before each comment. Continue in item 73 and use additional sheets if necessary.*)

(Continue in item 73)

44. DENTAL (*Place appropriate symbols, shown in examples, above or below number of upper and lower teeth.*)



RIGHT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	LEFT
	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	

REMARKS AND ADDITIONAL DENTAL DEFECTS AND DISEASES

LABORATORY FINDINGS

45. URINALYSIS A. SPECIFIC GRAVITY		46. CHEST X-RAY (*Place, date, film number and result*)
B. ALBUMIN	D. MICROSCOPIC	
C. SUGAR		

47. SEROLOGY (*Specify test used and result*)	48. EKG	49. BLOOD TYPE AND RH FACTOR	50. OTHER TESTS

88-118

MEASUREMENTS AND OTHER FINDINGS

51. HEIGHT	52. WEIGHT	53. COLOR HAIR	54. COLOR EYES	55. BUILD: ☐ SLENDER ☐ MEDIUM ☐ HEAVY ☐ OBESE	56. TEMPERATURE

57. BLOOD PRESSURE (*Arm at heart level*)						58. PULSE (*Arm at heart level*)				
A. SITTING	SYS.	B. RECUMBENT	SYS.	C. STANDING (*3 min.*)	SYS.	A. SITTING	B. AFTER EXERCISE	C. 2 MIN. AFTER	D. RECUMBENT	E. AFTER STANDING 3 MIN.
	DIAS.		DIAS.		DIAS.					

59. DISTANT VISION		60. REFRACTION			61. NEAR VISION		
RIGHT 20/	CORR. TO 20/	BY	S.	CX		CORR. TO	BY
LEFT 20/	CORR. TO 20/	BY	S.	CX		CORR. TO	BY

62. HETEROPHORIA (*Specify distance*)

ES° EX° R. H. L. H. PRISM DIV. PRISM CONV. CT PC PD

63. ACCOMMODATION RIGHT LEFT	64. COLOR VISION (*Test used and result*)	65. DEPTH PERCEPTION (*Test used and score*)	UNCORRECTED CORRECTED
66. FIELD OF VISION	67. NIGHT VISION (*Test used and score*)	68. RED LENS TEST	69. INTRAOCULAR TENSION

70. HEARING

RIGHT WV /15 SV /15

LEFT WV /15 SV /15

71. AUDIOMETER

	250 *256*	500 *512*	1000 *1024*	2000 *2048*	3000 *2896*	4000 *4096*	6000 *6144*	8000 *8192*
RIGHT								
LEFT								

72. PSYCHOLOGICAL AND PSYCHOMOTOR (*Tests used and score*)

73. NOTES (*Continued*) AND SIGNIFICANT OR INTERVAL HISTORY

(*Use additional sheets if necessary*)

74. SUMMARY OF DEFECTS AND DIAGNOSES (*List diagnoses with item numbers*)

75. RECOMMENDATIONS—FURTHER SPECIALIST EXAMINATIONS INDICATED (*Specify*)

76. A. PHYSICAL PROFILE

P	U	L	H	E	S

77. EXAMINEE (*Check*)

A. ☐ IS QUALIFIED FOR

B. ☐ IS NOT QUALIFIED FOR

B. PHYSICAL CATEGORY

A	B	C	E

78. IF NOT QUALIFIED LIST DISQUALIFYING DEFECTS BY ITEM NUMBER

79. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE	
80. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE	
81. TYPED OR PRINTED NAME OF DENTIST OR PHYSICIAN (*Indicate which*)	SIGNATURE	
82. TYPED OR PRINTED NAME OF REVIEWING OFFICER OR APPROVING AUTHORITY	SIGNATURE	NUMBER OF ATTACHED SHEETS

PO:1982-0-361-528/8087

STANDARD FORM 93
REV. OCTOBER 1974
GSA FPMR 101-11.8

APPROVED
OFFICE OF MANAGEMENT AND BUDGET No. 29-R0191

REPORT OF MEDICAL HISTORY

(THIS INFORMATION IS FOR OFFICIAL AND MEDICALLY-CONFIDENTIAL USE ONLY AND WILL NOT BE RELEASED TO UNAUTHORIZED PERSONS)

1. LAST NAME—FIRST NAME—MIDDLE NAME

2. SOCIAL SECURITY OR IDENTIFICATION NO.

3. HOME ADDRESS *(No. street or RFD, city or town, State, and ZIP CODE)*

4. POSITION *(title, grade, component)*

5. PURPOSE OF EXAMINATION

6. DATE OF EXAMINATION

7. EXAMINING FACILITY OR EXAMINER, AND ADDRESS *(Include ZIP Code)*

8. STATEMENT OF EXAMINEE'S PRESENT HEALTH AND MEDICATIONS CURRENTLY USED *(Follow by description of past history, if complaint exists)*

9. HAVE YOU EVER *(Please check each item)*			10. DO YOU *(Please check each item)*		
YES	NO	*(Check each item)*	YES	NO	*(Check each item)*
		Lived with anyone who had tuberculosis			Wear glasses or contact lenses
		Coughed up blood			Have vision in both eyes
		Bled excessively after injury or tooth extraction			Wear a hearing aid
		Attempted suicide			Stutter or stammer habitually
		Been a sleepwalker			Wear a brace or back support

11. HAVE YOU EVER HAD OR HAVE YOU NOW *(Please check at left of each item)*

YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*
			Scarlet fever, erysipelas				Cramps in your legs				"Trick" or locked knee
			Rheumatic fever				Frequent indigestion				Foot trouble
			Swollen or painful joints				Stomach, liver, or intestinal trouble				Neuritis
			Frequent or severe headache				Gall bladder trouble or gallstones				Paralysis (include infantile)
			Dizziness or fainting spells				Jaundice or hepatitis				Epilepsy or fits
			Eye trouble				Adverse reaction to serum, drug,				Car, train, sea or air sickness
			Ear, nose, or throat trouble				or medicine				Frequent trouble sleeping
			Hearing loss				Broken bones				Depression or excessive worry
			Chronic or frequent colds				Tumor, growth, cyst, cancer				Loss of memory or amnesia
			Severe tooth or gum trouble				Rupture/hernia				Nervous trouble of any sort
			Sinusitis				Piles or rectal disease				Periods of unconsciousness
			Hay Fever				Frequent or painful urination				
			Head injury				Bed wetting since age 12				
			Skin diseases				Kidney stone or blood in urine				
			Thyroid trouble				Sugar or albumin in urine				
			Tuberculosis				VD—Syphilis, gonorrhea, etc.				
			Asthma				Recent gain or loss of weight				
			Shortness of breath				Arthritis, Rheumatism, or Bursitis				
			Pain or pressure in chest				Bone, joint or other deformity				
			Chronic cough				Lameness				
			Palpitation or pounding heart				Loss of finger or toe				12. FEMALES ONLY: HAVE YOU EVER
			Heart trouble				Painful or "trick" shoulder or elbow				Been treated for a female disorder
			High or low blood pressure				Recurrent back pain				Had a change in menstrual pattern

13. WHAT IS YOUR USUAL OCCUPATION?

14. ARE YOU *(Check one)*

☐ Right handed ☐ Left handed

93-102

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YES	NO	CHECK EACH ITEM YES OR NO. EVERY ITEM CHECKED YES MUST BE FULLY EXPLAINED IN BLANK SPACE ON RIGHT	
		15. Have you been refused employment or been unable to hold a job or stay in school because of: A. Sensitivity to chemicals, dust, sunlight, etc.	
		B. Inability to perform certain motions.	
		C. Inability to assume certain positions.	
		D. Other medical reasons *(If yes, give reasons.)*	
		16. Have you ever been treated for a mental condition? *(If yes, specify when, where, and give details).*	
		17. Have you ever been denied life insurance? *(If yes, state reason and give details.)*	
		18. Have you had, or have you been advised to have, any operations? *(If yes, describe and give age at which occurred.)*	
		19. Have you ever been a patient in any type of hospitals? *(If yes, specify when, where, why, and name of doctor and complete address of hospital.)*	
		20. Have you ever had any illness or injury other than those already noted? *(If yes, specify when, where, and give details.)*	
		21. Have you consulted or been treated by clinics, physicians, healers, or other practitioners within the past 5 years for other than minor illnesses? *(If yes, give complete address of doctor, hospital, clinic, and details.)*	
		22. Have you ever been rejected for military service because of physical, mental, or other reasons? *(If yes, give date and reason for rejection.)*	
		23. Have you ever been discharged from military service because of physical, mental, or other reasons? *(If yes, give date, reason, and type of discharge: whether honorable, other than honorable, for unfitness or unsuitability.)*	
		24. Have you ever received, is there pending, or have you applied for pension or compensation for existing disability? *(If yes, specify what kind, granted by whom, and what amount, when, why.)*	

I certify that I have reviewed the foregoing information supplied by me and that it is true and complete to the best of my knowledge.
I authorize any of the doctors, hospitals, or clinics mentioned above to furnish the Government a complete transcript of my medical record for purposes of processing my application for this employment or service.

TYPED OR PRINTED NAME OF EXAMINEE	SIGNATURE

NOTE: HAND TO THE DOCTOR OR NURSE, OR IF MAILED MARK ENVELOPE "TO BE OPENED BY MEDICAL OFFICER ONLY."

25. Physician's summary and elaboration of all pertinent data *(Physician shall comment on all positive answers in items 9 through 24. Physician may develop by interview any additional medical history he deems important, and record any significant findings here.)*

TYPED OR PRINTED NAME OF PHYSICIAN OR EXAMINER	DATE	SIGNATURE	NUMBER OF ATTACHED SHEETS

REVERSE OF STANDARD FORM 93

☆U.S.GPO:1982-0-361-526/8042

APPENDIX F

BASIC DECONTAMINATION PROCEDURES

ANNEX 1

LEVEL A DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level A protection (with taped joints between gloves, boots, and suit) consisting of:

- Fully encapsulating suit with integral boots and gloves.
- Self-contained breathing apparatus.
- Hard hat (optional).
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water.

Equipment: container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash fully encapsulating suit and boots. Scrub suit and boots with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes

Station 8: Suit/Safety Boot Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 9: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boots covers donned, and joints taped. Worker then returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: Fully Encapsulating Suit and Hard Hat Removal

With assistance of helper, remove fully encapsulating suit (and hard hat). Hang suits on rack or lay out on drop cloths.

Equipment: rack
drop cloths
bench or stool

Station 12: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment: table

Station 13: Inner Glove Wash

Wash with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: basin or bucket
decon solution
or
detegent/water
small table

Station 14: Inner Glove Rinse

Rinse with water. Repeat as many times as necessary.

Equipment: water
basin or bucket
small table

Station 15: Facepiece Removal

Remove facepiece. Deposit in container with plastic liner. Avoid touching face with fingers.

Equipment: container (30-50 gallons)
plastic liners

Station 16: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 17: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off-site since there is a possibility that small amounts of contaminants might have been transferred in removing fully encapsulating suit.

Equipment: container (30-50 gallons)
plastic liners

Station 18: Field Wash

Shower if highly toxic, skin-corrosive or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap
small table
basin or bucket
field showers
towels

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

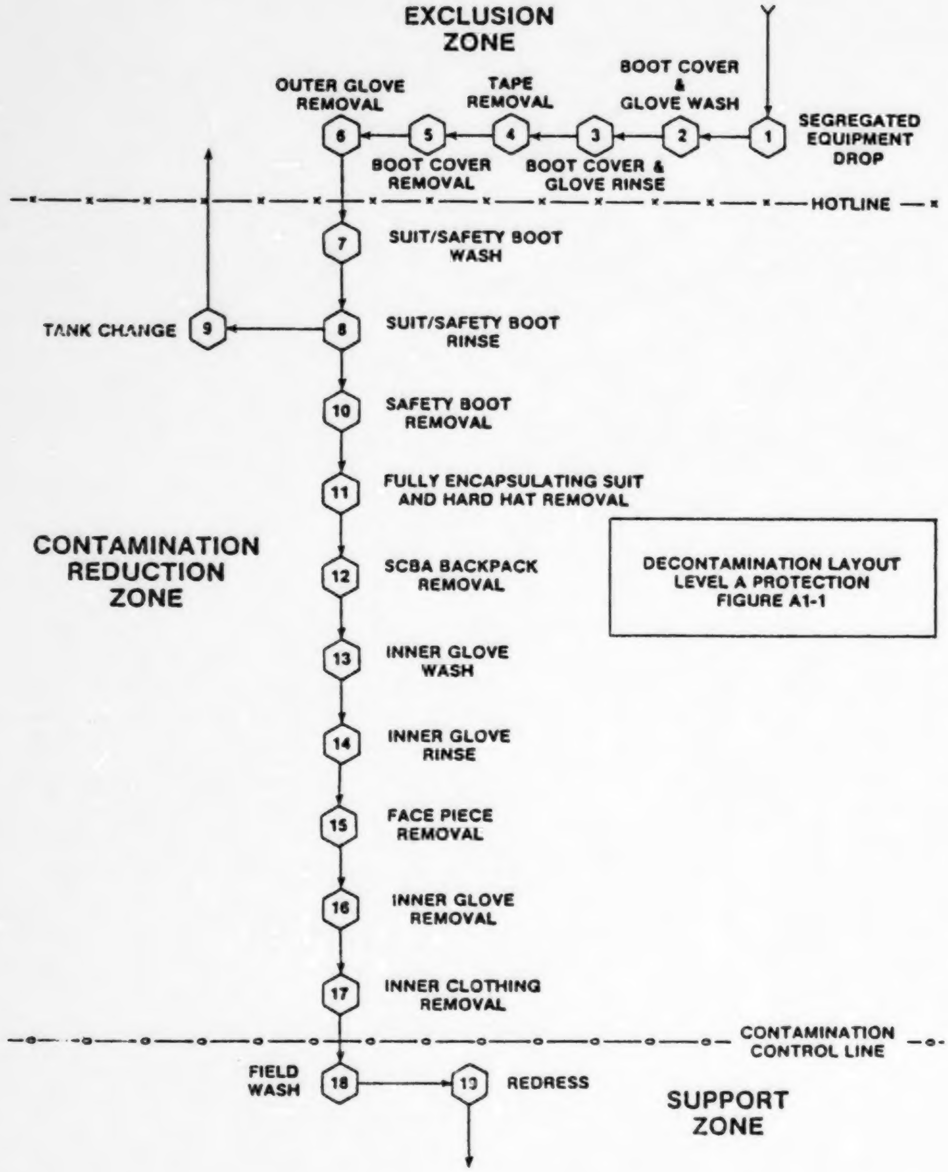
SIT	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X			X	X	X	X	
4	X						X	X	X										

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely toxic substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new air tank and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new air tank and will return to Exclusion Zone.



DECONTAMINATION LAYOUT
LEVEL A PROTECTION
FIGURE A1-1

ANNEX 2

LEVEL B DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level B protection (with taped joints between gloves, boot, and suit) consisting of:

- One-piece, hooded, chemical-resistant splash suit.
- Self-contained breathing apparatus.
- Hard hat.
- Chemical-resistant, steel toe and shank boots.
- Boot covers
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/ water.

Equipment: container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash chemical-resistant splash suit, SCBA, gloves, and safety boots. Scrub with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Wrap SCBA regulator (if belt-mounted type) with plastic to keep out water. Wash backpack assembly with sponges or cloths.

Equipment: container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes
small buckets
sponges or cloths

Station 8: Suit/SCBA/Boot/Glove Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
small buckets
2-3 long-handle, soft-bristle scrub brushes
sponges or cloths

Station 9: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boots covers donned, and joints taped. Worker returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment: table

Station 12: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 13: Inner Glove Wash

Wash inner gloves with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: decon solution
or
detergent/water
basin or bucket
small table

Station 14: Inner Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment: water
basin or bucket
small table

Station 15: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners

Station 16: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 17: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off-site since there is a possibility small amounts of contaminants might have been transferred in removing fully encapsulating suit.

Equipment: container (30-50 gallons)
plastic liners

Station 18: Field Wash

Shower if highly toxic, skin-corrosive, or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap

small tables
basins or buckets
field showers

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

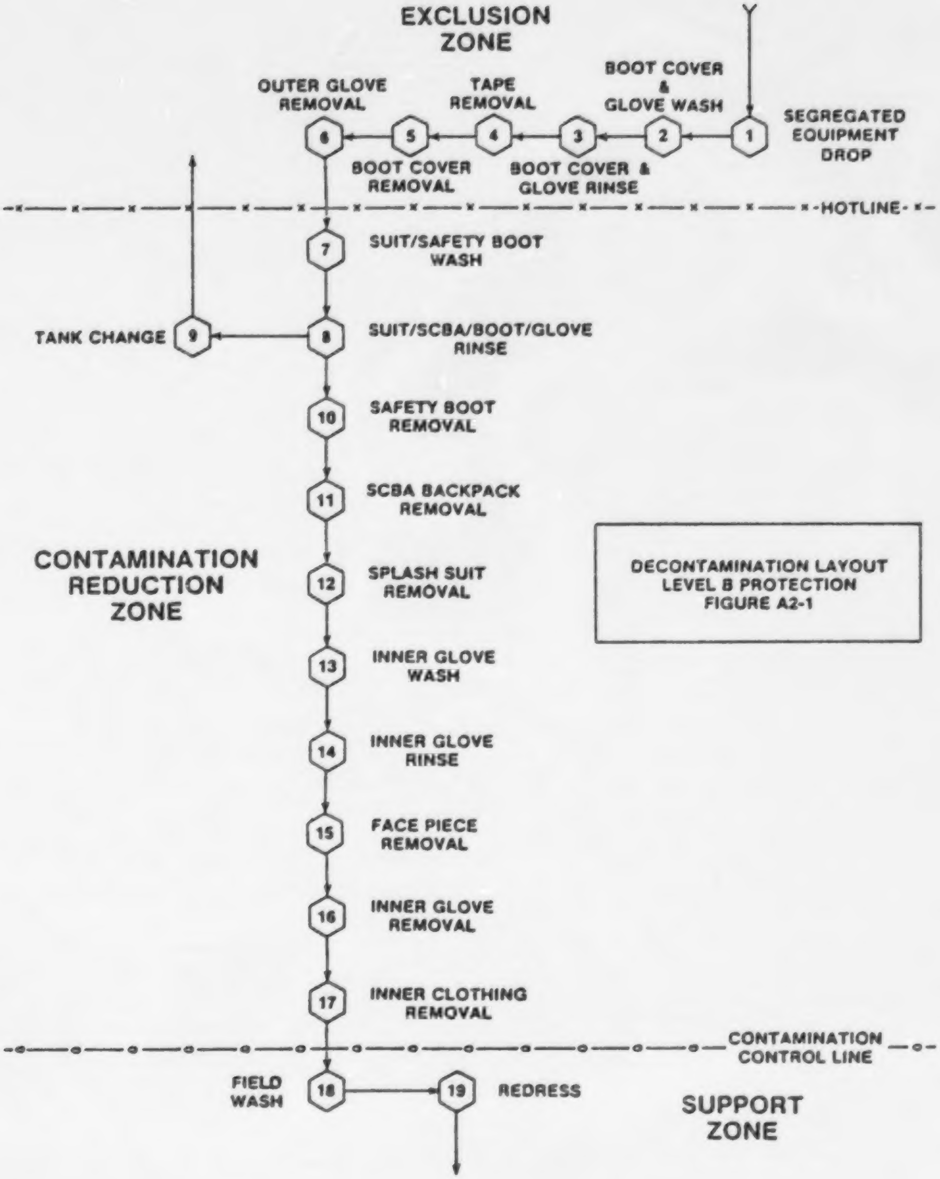
SIT	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X			X	X	X	X	
4	X						X	X	X										

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely toxic substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new air tank and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new air tank and will return to Exclusion Zone.



DECONTAMINATION LAYOUT
LEVEL B PROTECTION
FIGURE A2-1

ANNEX 3

LEVEL C DECONTAMINATION

A. EQUIPMENT WORN

The full decontamination procedure outlined is for workers wearing Level C protection (with taped joints between gloves, boots, and suit) consisting of:

- One-piece, hooded, chemical-resistant splash suit.
- Canister equipped, full-face mask.
- Hard hat.
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/ water.

Equipment: container (20-30 gallons)
decon solution
or
detergent water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 6: Outer Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 7: Suit/Safety Boot Wash

Thoroughly wash splash suit and safety boots. Scrub with long-handle, soft-bristle scrub brush and copious amounts of decon solution or detergent/water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
decon solution
or
detergent/water
2-3 long-handle, soft-bristle scrub brushes

Station 8: Suit/Safety Boot Rinse

Rinse off decon solution or detergent/water using copious amounts of water. Repeat as many times as necessary.

Equipment: container (30-50 gallons)
or
high-pressure spray unit
water
2-3 long-handle, soft-bristle scrub brushes

Station 9: Canister or Mask Change

If worker leaves Exclusion Zone to change canister (or mask), this is the last step in the decontamination procedure. Worker's canister is exchanged, new outer gloves and boots covers donned, and joints taped. Worker returns to duty.

Equipment: canister (or mask)
tape
boot covers
gloves

Station 10: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool
boot jack

Station 11: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
bench or stool
plastic liner

Station 12: Inner Glove Wash

Wash inner gloves with decon solution or detergent/water that will not harm skin. Repeat as many times as necessary.

Equipment: decon solution
or
detergent/water
basin or bucket

Station 13: Inner Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment: water
basin or bucket
small table

Station 14: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit facepiece in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners

Station 15: Inner Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment: container (20-30 gallons)
plastic liners

Station 16: Inner Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off-site since there is a possibility small amounts of contaminants might have been transferred in removing fully encapsulating suit.

Equipment: container (30-50 gallons)
plastic liners

Station 17: Field Wash

Shower if highly toxic, skin-corrosive or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment: water
soap
tables
wash basins/buckets
field showers

Station 18: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment: tables
chairs
lockers
clothes

C. FULL DECONTAMINATION (SIT. 1) AND THREE MODIFICATIONS

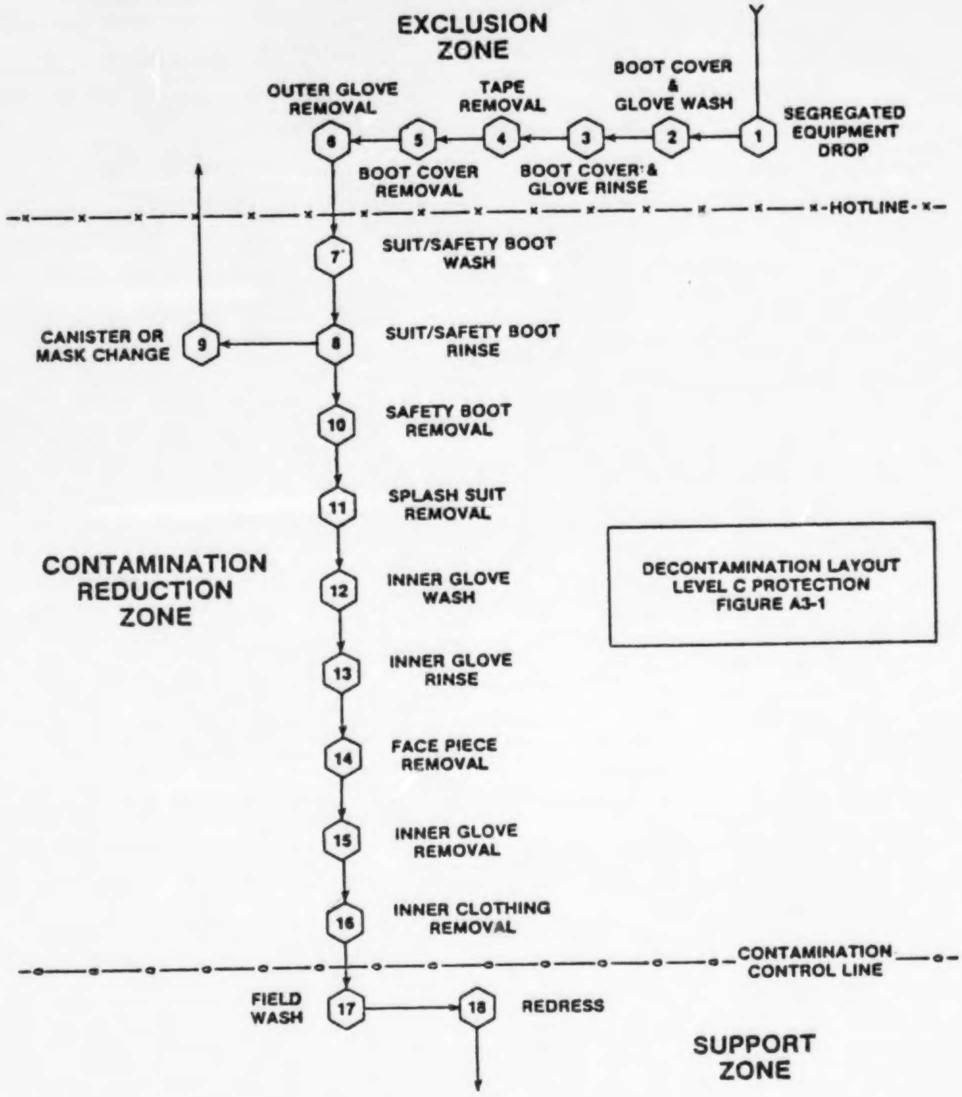
SIT	STATION NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X									
3	X						X	X		X	X			X	X	X	X	
4	X						X	X	X									

Situation 1: The individual entering the Contamination Reduction Corridor is observed to be grossly contaminated or extremely skin-corrosive substances are known or suspected to be present.

Situation 2: Same as Situation 1 except individual needs new canister or mask and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as Situation 3 except individual needs new canister or mask and will return to Exclusion Zone.



DECONTAMINATION LAYOUT
LEVEL C PROTECTION
FIGURE A3-1

ANNEX 4

LEVEL A DECONTAMINATION, MINIMUM LAYOUT

A. EQUIPMENT WORN

The decontamination procedure outlined is for workers wearing Level A protection (with taped joints between gloves, boots, and suit) consisting of:

- Fully encapsulating suit with integral boots and gloves.
- Self-contained breathing apparatus.
- Hard hat (optional).
- Chemical-resistant, steel toe and shank boots.
- Boot covers.
- Inner and outer gloves.

B. PROCEDURE FOR FULL DECONTAMINATION

Station 1: Segregated Equipment Drop

Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment: various size containers
plastic liners
plastic drop clothes

Station 2: Outer Garment, Boots, and Gloves Wash and Rinse

Scrub outer boots, outer gloves, and fully-encapsulating suit with decon solution or detergent water. Rinse off using copious amounts of water.

Equipment: containers (30-50 gallons)
decon solution
or
detergent water
rinse water
2-3 long-handle, soft-bristle scrub brushes

Station 3: Outer Boot and Glove Removal

Remove outer boots and gloves. Deposit in container with plastic liner.

Equipment: container (30-50 gallons)
plastic liners
bench or stool

Station 4: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boot covers donned, joints taped, and worker returns to duty.

Equipment: air tanks
tape
boot covers
gloves

Station 5: Boot, Gloves, and Outer Garment Removal

Boots, fully-encapsulating suit, and inner gloves removed and deposited in separate containers lined with plastic.

Equipment: containers (30-50 gallons)
plastic liners
bench or stool

Station 6: SCBA Removal

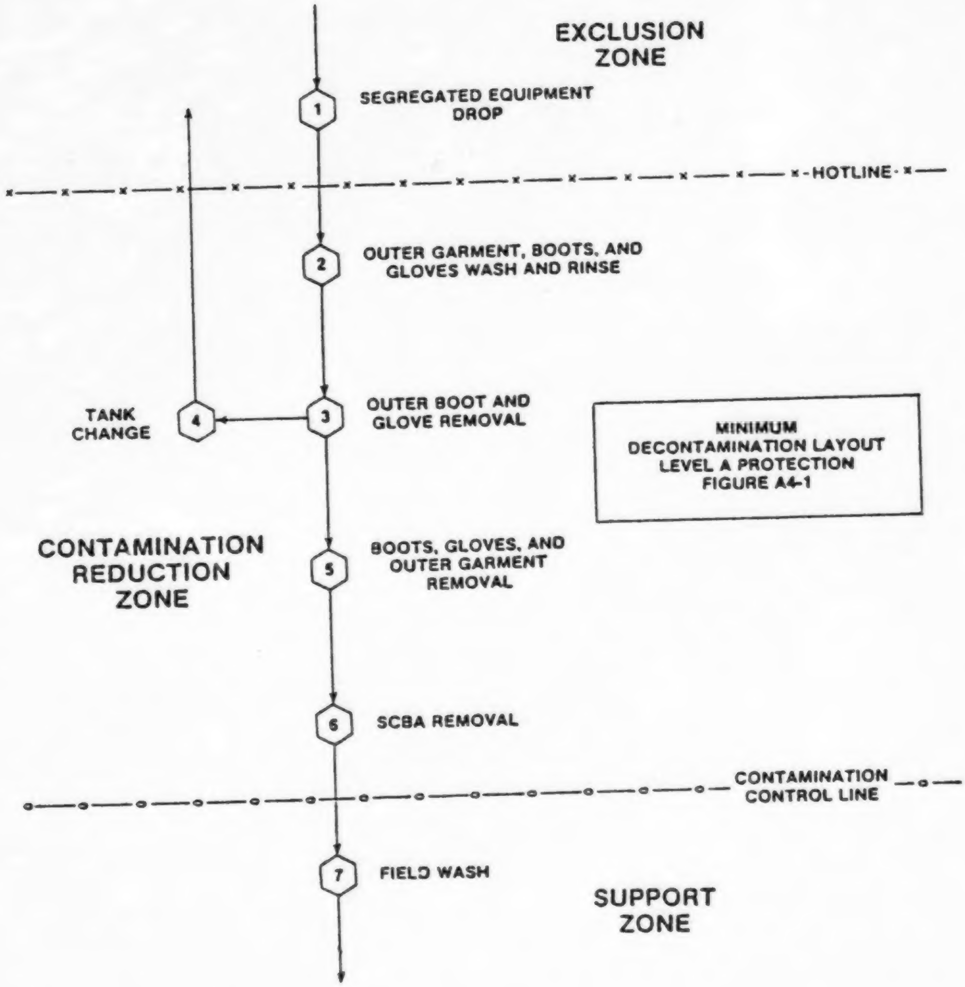
SCBA backpack and facepiece is removed. Hands and face are thoroughly washed. SCBA deposited on plastic sheets.

Equipment: plastic sheets
basin or bucket
soap and towels
bench

Station 7: Field Wash

Thoroughly wash hands and face. Shower as soon as possible.

Equipment: water
soap
tables
wash basin/bucket


EXCLUSION ZONE
1
SEGREGATED EQUIPMENT DROP
HOTLINE
2
OUTER GARMENT, BOOTS, AND GLOVES WASH AND RINSE
TANK CHANGE
4
3
OUTER BOOT AND GLOVE REMOVAL
CONTAMINATION REDUCTION ZONE
5
BOOTS, GLOVES, AND OUTER GARMENT REMOVAL
6
SCBA REMOVAL
CONTAMINATION CONTROL LINE
7
FIELD WASH
SUPPORT ZONE

MINIMUM
DECONTAMINATION LAYOUT
LEVEL A PROTECTION
FIGURE A4-1

APPENDIX G

SOURCES OF INFORMATION AND RESPONSE ASSISTANCE

I. INTRODUCTION

Many sources of information and organizations can provide response personnel with technical data and physical assistance regarding both the hazards associated with an incident and methods to deal with them. It is necessary to be aware of these resources and know how to use them.

The information, which may include data on sites, topography, meteorology, physical/chemical properties of the material, applicable treatment methods, and available cleanup resources, can be provided by various agencies, maps, reference books, and manuals. It is advisable to get data from at least two sources and use the latest addition of any reference, especially when searching for hygienic standards or toxicological data.

Access to on-line computer files may be possible at the site if a telephone, portable terminal, and 120-volt outlet are available. Aerial photographs can also provide useful information when properly interpreted.

II. BASIC REFERENCES

A. OHMTADS: Oil and Hazardous Materials Technical Assistance Data System, developed by the EPA. Access through EPA Regional Offices.

OHMTADS is a computerized data retrieval system available in the form of a computer print-out, manuals, or microfiche. For each of more than 1,000 oil and hazardous substances, there are 126 possible information segments on, for example, toxicity and associated hazards, personal safety precautions, cleanup and disposal methods, materials handling, and fire fighting. However, not all information is available for all materials.

B. CHRIS: Chemical Hazard Response Information System, developed by the U.S. Coast Guard. Access through the National Response Center, telephone 800/424-8802

CHRIS consists of four manuals, a regional contingency plan, a Hazard Assessment Computer System (HACS), and an organizational entity at Coast Guard Headquarters. Volume 1 (CG-446-1) is designed to be used by the first responders at an incident. Volumes 2, 3, and 4 (CG-446-2, CG-446-3, and CG-446-4, respectively) are intended for use by the On-Scene Coordinator's (OSC) office along with the Regional and National Response Centers. Coast Guard stations, especially those in major parts, will usually have these manuals.

1. Volume 1: "Condensed Guide to Chemical Hazards"

   Volume 1 is intended for use by the first responders on the scene of an incident. The chemicals involved must be known, however, before the appropriate information can be obtained from the manual. This volume also contains a list of questions needed to access Volume 3. All information in this volume can be found in Volume 2.

2. Volume 2: "Hazardous Substance Data Manual", (also available from the U.S. Government Printing Office, Washington, DC 20402, GPO stock number 050-012-00147-2)

   Volume 2 is probably the most useful in responding to spills/waste sites. Containing information on hazardous chemicals shipped in large volume by water, it is intended to be used by port security personnel and others who may be first to arrive at the scene. The easily understood information about chemical, physical, and toxicological properties can help quickly determine the actions to be taken immediately to safeguard life, property, and the environment.

3. Volume 3: "Hazard Assessment Handbook"

   Volume 3 describes methods of estimating the quantity of chemicals which may be released during an incident, their rate of dispersion, and the methods for predicting any potential toxic, fire, and explosive hazards.

   Volumes 2 and 3 are designed to be used together. The hazard assessment code in Volume 2 for each chemical is used in Volume 3 to select the appropriate procedures to calculate hazard assessment.

4. Volume 4: "Response Methods Handbook"

   Volume 4 contains information on existing methods for handling spills of hazardous materials. The appendix lists manufacturers of equipment which may be useful. It also describes methods of spill (primarily oil), containment. This volume is intended for use by Coast Guard OSCs with some training or experience in hazard response.

C. "Documentation of the Threshold Limit Values (TLV)", fourth edition (1980), ACGIH Publications Office, 6500 Glenway Ave., Building D-5, Cincinnati, OH 45221

This book gives pertinent scientific information, with references to literature sources used to determine each TLV. Each documentation also defines the type of toxic response for which the limit is used. This book should be consulted for a better understanding of TLV's.

(See Part 5, "Threshold Limit Values and Other Guidelines.")

D. National Institute of Occupational Safety and Health/Occupational Safety and Health Administration Resources

1. "NIOSH/OSHA Pocket Guide to Chemical Hazards," U.S. Government Printing Office, Washington, DC 20402

   Information in this pocket guide comes from the NIOSH/OSHA Occupational Health Guidelines. Presented in a tabular format, it is a reference for industrial hygiene and medical surveillance practices. Included are chemical names and synonyms, permissible exposure limits, chemical and physical properties, signs and symptoms of overexposure, environmental and medical monitoring procedures, recommended respiratory and personal protective equipment, and procedures for treatment.

2. "NIOSH/OSHA Occupational Health Guidelines for Chemical Hazard's," U.S. Government Printing Office, Washington, DC 20402

   This three-volume document provides technical data for most of the substances listed in the "NIOSH/OSHA Pocket Guide." The information is much more detailed and is designed primarily for use by industrial hygienists and medical surveillance personnel. In addition to the information found in the "Pocket Guide," "Occupational Health Guidelines" includes recommended medical surveillance practices, air monitoring and measurement procedures, personnel sanitation, and spill and disposal techniques.

E. "Fire Prevention Guide on Hazardous Materials," National Fire Protection Association (NFPA), Quincy, MA 02269

The NFPA has combined five manuals into one comprehensive guide on hazardous materials. These five present information on:

1. Flashpoint of oils, together with more than 8,800 trade-name chemicals, their flashpoints, manufacturers, and principal uses. The flammability hazard can be determined from this information.

2. Fire hazards of 1,300 flammable liquids, gases, and solids are listed in alphabetical order with appropriate fire-fighting information. Various properties listed include flashpoint, specific gravity, water solubility, hazard identification, and boiling point.

3. Toxicity data on 416 chemicals.

4. Hazardous reactions of over 3,550 chemicals. Reactions may involve two or more chemicals and cause fires, explosions, or other problems. A chemical is listed, followed by those chemicals which can cause a hazardous reaction.

5. Recommended system for identification of fire hazards of materials. The NFPA labeling system is described in detail, with a careful explanation of the ratings.

This manual presents a large amount of information, but deals with pure chemicals, not mixtures. Some experience is required to interpret the manual properly.

F. "The Merck Index," ninth edition (1976), Merck and Co., Inc., Raway, NJ 07065

"The Merck Index" is a comprehensive, interdisciplinary encyclopedia of chemicals, drugs, and biological substances. It describes 9,856 chemicals in a structured format. An extensive index and cross-index make the manual easy to use. It is designed to serve a variety of purposes. For response personnel, it provides information on physical/chemical properties of chemicals and their toxicity.

G. "Dangerous Properties of Industrial Materials," fourth edition (1975), edited by N. Irving Sax, Van Nostrand Reinhold, Co., 135 W. 50th St., New York, NY 10020

This book provides a single source of concise information on the hazards of nearly 13,000 common industrial and laboratory materials. Descriptive information and technical data are given in the three sections of the book. The main section, general information, is designed to expedite retrieval of hazard information. The three sections are:

1. General information: synonyms, description, formula, physical constants.

2. Hazard analysis: toxicity, fire hazard, explosive hazard.

3. Countermeasures: handling, storage, shipping, first aid, fire-fighting, personnel protection.

This book is not intended for use on site. It can be useful later, however, to verify hazards associated with the emergency.

H. "Condensed Chemical Dictionary," Gessner G. Hawley, Van Nostrand Reinhold Co., 135 W. 50th St., New York, NY 10020

This book, a compendium of technical data and descriptive information covering many thousands of chemicals and reactions, is designed for very quick use and can be helpful in assessing a hazardous waste site or spill. Three distinct types of information are presented:

1. Technical descriptions of compounds, raw materials, and processes.

2. Expanded definitions of chemical entities, phenomena, and terminology.

3. Description or identification of a wide range of trade-name products used in the chemical industry.

III. ON-LINE COMUPTER SYSTEMS

1. OHMTADS: Access through EPA Regional Offices

OHMTADS, EPA's computerized information retrieval system, can help identify material from observations (smell, color, etc.) made at each site. The information in the 126 segments covers a variety of physical, chemical, biological, toxicological, and commercial data, with the emphasis on the effects on water quality.

OHMTADS has a random access provision which enables the user to solve problems involving unidentified pollutants by inputting physical/chemical characteristics or other factors observed on-site. The system automatically takes each word and processes it into an inverted index file, making each word a search component of the data base. The search is made using Boolean logic, and the system responds with a list of the compounds meeting the input characteristics. The output is displayed on the user's terminal. The user can then refine the search if necessary to narrow the list of possible materials.

2. HACS: Hazard Assessment Computer System. Access through the National Response Center, telephone 800/424-8802

HACS, the computerized counterpart of Volume 3 of the CHRIS manuals, makes it possible to obtain very detailed hazard evaluations through the computer at Coast Guard Headquarters. The system is intended primarily for use by the OSC.

3. SKIM: Spill Clean-Up Inventory System, developed by the U.S. Coast Guard.

The U.S. Coast Guard's Office of Marine Environment and Systems, Pollution Response Branch, developed SKIM, a computer-based inventory of equipment available for pollution response in the United States (including Puerto Rico and Guam). The inventory includes public equipment, such as that owned by the Coast Guard, U.S. Navy, and other agencies, as well as equipment maintained by contractors, cooperatives, and private companies.

The information is readily available to interested parties through a network of computer terminals with access to the system. SKIM was designed with a variety of potential uses in mind. It can:

- Provide up-to-date information to OSC's. When a spill occurs and the predesignated OSC in that area is notified of the specific details, he is responsible for bringing the best combination of response resources to bear on the problem. SKIM helps make such decisions.

- Provide updates to equipment listings in local contingency plans. While many of these plans now are out of date, SKIM enables local and Regional Response Teams to obtain up-to-date listings.

- Serves as an informational aid for Coast Guard Marine Safety Offices, captains of the ports, and district and headquarters managers. This enhances the decision-making capability of those concerned with budgeting, resources allocation, and planning for pollution response.

- Be used by all Federal agencies involved with the National or Regional Response Teams.

4. Private Firms Offering Access to Data Banks

- SDC: System Development Corp., telephone 800/352-6689 (California), 800/421-7229 (Continental U.S., except California)

  The SDC Search service is one of the most comprehensive on-line retrieval services in the world. It provides easy, convenient access to one of the largest families of on-line literature and reference data bases obtainable anywhere - most of them available only through SDC. Its services include: ENVIROLINE, which contains citations on all areas of environmental studies and covers such subjects as air pollution, chemical and biological contamination, energy, environmental education, environmental design and urban ecology, population planning, and geographical changes. The use of modern telecommunications, SDC's computers, and ORBIT, its advanced, field-tested retrieval system, permits retrieving the necessary information quickly, precisely, and efficiently. Because of ORBIT's quick response characteristics, an effective search from start to finish can often be completed in as little as 5-10 minutes.

- Sigma Data Computing Corp., 926 Wayne Ave., Silver Spring, MD 20910, telephone 301/589-6101.

  This company provides computer services and products to governmental and commercial clients.

- Sigma Data Services, Corp., same address as above, telephone 301/565-3773.

  This company operates computer facilities and provides analysis and programming services for government agencies.

IV. REMOTE SENSING AND MAP INTERPRETATION

A. Aerial Photography

1. Environmental Photograph Interpretation Center, Warrenton, VA 22186, telephone 703/557-3110 (EPA Regions I-IV)

   Environmental Monitoring and Support Laboratory, Las Vegas, NV 89114, telephone 702/798-2237 (EPA Regions V-X)

   Aerial photography can be useful in a spill response in that a plane can fly over the area the time of the spill recording its extent. Subsequent flights can show the dispersion. Also, many different types of photography, including infrared, can help describe waste sites and plume dispersion. Historical photos can trace a facility from its inception to the present, pin-pointing past activities that may mark trouble spots.

   Aerial photography has another use, monitoring facilities that produce or store chemicals. Spill and spill-threat conditions that exist in many such facilities may also be photographically documented. Aerial photographers can assist with the monitoring of chemical facilities for compliance with the spill prevention regulations issued under the Federal Water Pollution Control Act as amended in 1977. Aerial reconnaissance missions effectively and economically augment compliance monitoring efforts of EPA Regions or other regulatory agencies. An airplane can fly over a large number of areas and facilities in a brief period of time. Once the photographs have been interpreted, spill prevention personnel can use the results to inspect areas or facilities in a minimum amount of time because they can concentrate on those areas with the spill problem.

2. EROS Data Center, User Services, Sioux Falls, SD 57198, telephone 504/594-6511, ext. 151

   The EROS system, run by the U.S. Geological Survey, uses remote-sensing techniques to inventory, monitor, and manage natural resources. EROS includes research and training in the interpretation and application of remotely sensed data and provides these data at nominal cost.

   At the heart of the EROS Data Center is a central computer complex which controls a data base of over 6 million images and photographs of the earth's surface features, searches for geographic data on areas of interest, and serves as a management tool for the entire data reproduction process. The computerized data storage and retrieval system is based on latitude and longitude, supplemented by information about image quality, cloud cover, and type of data.

Information received from the EROS Data Center can be used in much the same way as information received from the Environmental Monitoring and Support Laboratory. EROS data provide a chronological overview of an area, thereby establishing the extent of damage over time.

B. U.S. Geological Survey Maps

1. Topographic quandrangle maps

Topographic maps are useful in that they show the contours of the land, the network of water features, and elevations. They also show cities and urban areas and, in the case of a spill or waste site, they tell how close a spill or waste site is to a lake, river, stream, or population centers.

2. Hydrologic maps

Hydrologic maps show water in or beneath the land surface. They are very useful when evaluating water supply and water-related hazards such as flooding. They also show drainage areas, depth to ground water, and the thickness of water-bearing formations. In the case of a spill or waste site, a hydrologic map is can indicate any possible contamination of the ground water and/or drainage area.

3. Land use and land cover maps

Land use and land cover maps have been prepared by using the standard topographic quadrangle maps or larger-scale low-altitude aerial photographs as a base. These maps provide detailed information about the way people use the land or about the vegetation cover. This information could be useful at a spill or waste site. For example, if chemicals enter an area being used for crops, authorities should be advised of the chemical(s) involved and their possible effects.

4. Sources of maps

Maps are available in areas east of the Mississippi River, including Minnesota, Puerto Rico, and the Virgin Island, from:

Branch of Distribution
U.S. Geological Survey
1200 South Eads St.
Arlington, VA 22202
Telephone: 703/557-2751

Areas west of the Mississippi River, including Alaska, Hawaii, Louisiana, Guam, and American Somoa, should order from:

Branch of Distribution
U.S. Geological Survey
Box 25286, Federal Center
Denver, CO 80225
Telephone: 303/234-3832

V. TECHNICAL ASSISTANCE ORGANIZATIONS

A. Federal

1. IRAP: Interagency Radiological Assistance Plan. Access through CHEMTREC (see section B), telephone 800/424-8306 (24 hours), or 202/483-7616 in Washington, DC. Also through Regional Offices of EPA and Department of Energy (DOE).

   IRAP is designed to assist in coping with radiation emergencies. It operates through DOE, but works closely with other Federal, State, military, and regional groups. Upon receiving an emergency call, the regional coordinator of IRAP investigates the situation, getting as much information as possible as to the type of material. If the spill or leak appears serious, a technical response team is dispatched and the Nuclear Regulatory Commission is notified. The main functions of the response team are to assess the hazard, inform the public, and recommend emergency actions to minimize the hazard. The responsibility for cleanup rests with the shipper or carrier of the material at the time of the spill.

2. Coast Guard National Strike Force. Access through the National Response Center, telephone 800/424-8801.

   The National Strike Force (NSF) is a part of the National Response Team established under the authority of the Federal Water Pollution Control Act as amended in 1977. It consists of high seas oil cleanup equipment and trained personnel available to assist the OSC upon request during Phase III (Containment and Countermeasures), Phase IV (Cleanup, Mitigation, and Disposal), and Phase V (Documentation and Cost Recovery), as defined in the National Contingency Plan. A Coast Guard Strike Team is located on the East, West, and Gulf Coasts. Each is capable of responding to a pollution incident in its area with four or more men within 2 hours and be at full strength in 12 hours. The teams can provide communication support, assistance, and advice on ship salvage, diving, and removal techniques.

3. U.S. Army Technical (Escort Center). Chemical Emergency Response Team. Access through the Department of the Army, Operations Center, telephone 7-3/521-2185.

   This center maintains, on standby, a 14-man alert team at Aberdeen Proving Ground, MD, trained and experienced in handling chemical emergencies. It has readily available equipment such as decontamination trucks, air monitoring equipment, and protective clothing. This team can respond in 2 hours to a chemical emergency when directed to do so by the Army. Although it responds mainly to emergencies involving Department of the Army chemicals, it assists the other agencies such as the Coast Guard and EPA.

4. Environmental Response Team (ERT)

The National Contingency Plan directed EPA to establish the ERT to advise OSC's and Regional Response Teams on environmental issues related to spill containment, cleanup, and damage assessment. The team, established in October 1978, provides expertise in biology, chemistry, and engineering for environmental emergencies, as well as special equipment to control and clean up chemical discharges.

The ERT makes it possible for EPA to provide around-the-clock support to the Regional Offices through personnel whose sole responsibility is to respond to environmental emergencies. The Team is EPA's focal point for technical assistance to the Regions and Program Offices during emergency episodes involving toxic and hazardous wastes. The Team has two locations: Edison, NJ, and Cincinnati, OH. Usually, requests for help from the Team comes from each Region's Emergency Coordinator, once the conclusion has been reached that technical assistance is needed. The Team consists of 11 individuals with long experience in dealing with various types of environmental emergencies and in responding to requests for assistance at uncontrolled hazardous waste sites.

The Team is responsible for coordinating the Environmental Emergency Response Unit (EERU), a cooperative effort between the Team, the Office of Research and Development's Oil and Hazardous Materials Spills Branch, and contractor personnel. Services available through the Response Unit include prototype spill control equipment such as the mobile physical/chemical treatment system, a mobile flocculation/sedimentation system, contract laboratory analytical services, and pilot plant treatment studies.

B. Private

1. CHEMTREC: Chemical Transportation Emergency Center. Access via telephone, 800/424-9300 or 202/483-7616 in Washington, DC.

CHEMTREC is a clearinghouse providing a 24-hour telephone number for chemical transportation emergencies. It covers over 3,600 chemicals which have been submitted by manufactuers as the primary materials they ship. CHEMTREC is sponsored by the Chemical Manufacturers Association, although nonmembers are also served. The emergency telephone number is widely distributed to emergency service personnel, carriers, and the chemical industry. The number is usually given on the bill of lading.

When an emergency call is received by CHEMTREC, the person on duty writes down the essential information. As much information as possible is obtained by phone. The person on duty gives the caller information on hazards of spills, fire, or exposure that the manufacturers of the chemicals involved had furnished. The person on duty then notifies the shipper of the chemical by phone of the situation. At this point, responsiblity for further guidance passes to the shipper.

CHEMTREC's function is basically to serve as the liaison between the person with the problem and the chemical shipper and/or the manufacturer, the people who know the most about the product and its properties.

2. CHLOREP: Chlorine Emergency Plan. Accesss through CHEMTREC.

   CHLOREP was established by the Chlorine Institute to handle chlorine emergencies in the U.S. and Canada. The system operates through CHEMTREC. Upon receiving an emergency call, CHEMTREC notifies the nearest manufacturer in accordance with a mutual aid plan. This manufacturer then contacts the emergency scene to determine if a technical team should be sent to assist. Each participating manufacturer has trained personnel and equipment available for emergencies.

3. National Agricultural Chemicals Association, Pesticide Safety Team Network. Access through CHEMTREC.

   The National Agricultural Chemicals Association operates a national pesticide information and response network providing advice and on-site assistance when a spill warrants it. The network operates through CHEMTREC. Upon receiving notification of an emergency involving a pesticide, CHEMTREC contacts the manufacturer, who provides specific advice on handling the spill. If necessary, spill response teams are available on a geographical basis.

4. TEAP: Transportation Emergency Assistance Plan, Canadian Chemical Producers Association. Access 24 hours a day through three regional control centers:

   - British Columbia, 604/929-3341
   - Prairie Provinces, 403/477-8339
   - Northern Ontario, 705/682-2881

   TEAP functions in Canada in a similar fashion to CHEMTREC in the U.S. It provides emergency advice, gets knowledgeable personnel (usually the manufacturer) in touch with responsible people at the scene of the emergency, and sees that on-the-scene assistance is provided if needed. When the regional control center receives a call, the attendant records basic information, obtains a call-back number, and perhaps gives preliminary information from standard references if the name of the product is known. The attendant then calls one of the center's technical advisors, who calls the scene of the accident to get as much detail as possible and perhaps provides additional advice on coping with the emergency. The advisor then tries to contact the producer. If the producer cannot be reached, or if distances are great, the regional control center contacts a company familiar with the product. The center is also prepared to send personnel and equipment to the scence if necessary. Once contact has been established between producer and local authorities on the scene, the technical advisor assumes a follow-up role and notifies the Canadian Chemical Producers Association of the accident.

REFERENCES AND RESOURCES

I. INTRODUCTION

This reference list is meant to provide the titles of books which may be of value to those responding to hazardous material incidents. Many more books are available which are not named here. This list can be expanded based on personal preferences and requirements.

The references are categorized by subject. The title, author, publisher, and place of publication are given for each. The year of publication is not always given because many are revised annually. The user should attempt to obtain the most recent edition.

The last section lists sources of these references as well as other information that might be useful. Usually, these agencies or associations will provide a catalogue on request. Where available, phone numbers are also listed.

II. REFERENCES

A. Industrial Hygiene (Air Sampling and Monitoring, Respiratory Protection, Toxicology)

1. Air Sampling Instruments for Evaluation of Atmospheric Contaminants, American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

2. Basic Industrial Hygiene, Richard Brief, American Industrial Hygiene Association, Akron, OH.

3. Direct Reading Colorimetric Indicator Tubes Manual, American Industrial Hygiene Association, Akron, OH.

4. Documentation of the Threshold Limit Values (TLV), American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

5. Fundamentals of Industrial Hygiene, National Safety Council, Chicago, IL.

6. The Industrial Environment - Its Evaluation and Control, National Institute for Occupational Safety and Health, Rockville, MD.

7. Industrial Hygiene and Toxicology, Frank A. Patty, John Wiley and Sons, Inc., New York, NY.

8. Manual of Recommended Practice for Combustible Gas Indicators and Portable, Direct Reading Hydrocarbon Detectors, American Industrial Hygiene Association, Akron, OH.

9. Occupational Health Guidelines for Chemical Hazards, National Institute for Occupational Safety and Health, Rockville, MD.

10. Registry of Toxic Effects of Chemical Substances, National Institute for Occupational Safety and Health, Rockville, MD.

11. Respiratory Protective Devices Manual, American Industrial Hygiene Association, Akron, OH.

12. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment, American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

B. Chemical Data

1. Chemical Hazard Response Information System, Volume 2: Chemical Data, U.S. Coast Guard, Washington, DC.

2. Chemistry of Hazardous Materials, Eugene Meyer, Prentice-Hall, Englewood Cliffs, NJ.

3. The Condensed Chemical Dictionary, G. Hawley, Van Nostrand Reinhold Co., New York, NY.

4. CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, FL.

5. Dangerous Properties of Industrial Materials, N. Irving Sax, Van Nostrand Reinhold Co., New York, NY.

6. Fire Protection Guide to Hazardous Materials, National Fire Protection Association, Boston, MA.

7. Hygienic Guides, American Industrial Hygiene Association, Akron, OH.

8. The Merck Index, Merck and Co., Inc., Rahway, NJ.

9. Toxic and Hazardous Industrial Chemicals Safety Manual, The International Technical Information Institute, Tokyo, Japan.

8. Manual of Recommended Practice for Combustible Gas Indicators and Portable, Direct Reading Hydrocarbon Detectors, American Industrial Hygiene Association, Akron, OH.

9. Occupational Health Guidelines for Chemical Hazards, National Institute for Occupational Safety and Health, Rockville, MD.

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4. CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, FL.

5. Dangerous Properties of Industrial Materials, N. Irving Sax, Van Nostrand Reinhold Co., New York, NY.

6. Fire Protection Guide to Hazardous Materials, National Fire Protection Association, Boston, MA.

7. Hygienic Guides, American Industrial Hygiene Association, Akron, OH.

8. The Merck Index, Merck and Co., Inc., Rahway, NJ.

9. Toxic and Hazardous Industrial Chemicals Safety Manual, The International Technical Information Institute, Tokyo, Japan.

C. EPA Methods Manuals for Sampling and Analysis

1. Biological Field and Laboratory Methods for Measuring the Quality of Surface Water and Effluents, EPA-670/4-73-001 (July 1973).
2. EPA Solid Waste Manual, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846 (May 1980).
3. Handbook for Analytical Quality Control in Water and Wastewater Laboratories, EPA-600/4-79-019 (March 1979).
4. Methods of Chemical Analysis of Water and Wastes, EPA-600/4-79-020 (March 1979).
5. Microbiological Methods for Monitoring the Environment, Water and Wastes, EPA-600/8-78-017 (December 1978).
6. Procedures Manual for Groundwater Monitoring at Solid Wastes Disposal Facilities, EPA-530/SW-611 (August 1977).

D. Safety

1. Best's Safety Directory, A.M. Best Co., Oldwick, NJ.
2. CRC Handbook of Laboratory Safety, Norman V. Steere, CRC Press, Boca Raton, FL.
3. Fire Protection Handbook, National Fire Protection Association, Quincy, MA.
4. FM Approval List, Factory Mutual, Norwood, MA.
5. National Safety Council Safety Sheets, National Safety Council, Chicago, IL.
6. Underwriters Laboratories Testing for Public Safety, Annual Directory, Underwriters Laboratories Inc., Northbrook, IL.

III. AGENCIES AND ASSOCIATIONS

American Conference of Governmental Industrial Hygienists
6500 Glenway Ave. - Building D-5
Cincinnati, OH 45211
513/661-7881

American Industrial Hygiene Association
475 Wolf Ledges Parkway
Akron, OH 44311-1087
216/762-7294

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018
212/354-3300

Compressed Gas Association
1235 Jefferson Davis Highway
Arlington, VA 22202
703/979-0900

CRC Press, Inc.
2000 Corporate Blvd., N.W.
Boca Raton, FL 33431
305/994-0555, Ext. 330

EPA Office of Research & Development
Publications - CERI
Cincinnati, OH 45268
513/684-7562

EPA Office of Solid Waste (WH-562)
401 M. St., S.W.
Washington, DC 20460
800/424-9346

Materials Transportation Bureau
Department of Transportation
Research and Special Programs Administration
Washington, DC 20590
202/426-2301

Mine Safety and Health Administration
Department of Labor
4015 Wilson Blvd, Room 600
Arlington, VA 22203
703/235-1452

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269
617/328-9290

National Safety Council
444 North Michigan Ave.
Chicago, Il 60611
312-527-4800

NIOSH Publications Dissemination
4676 Columbia Parkway
Cincinnati, OH 45226
513/684-4287

Occupational Safety & Health Administration
Department of Labor
200 Constitution Ave., N.W.
Washington, DC 20210
202/523-6138

Underwriters Laboratories, Inc.
333 Pfongsten Rd.
Northbrook, IL 60062
312/272-8800

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402
202/783-3238